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HANDBOOK
OPERATING INSTRUCTIONS

AUTOMATIC ASTRO COMPASS

(TITLE UNCLASSIFIED)

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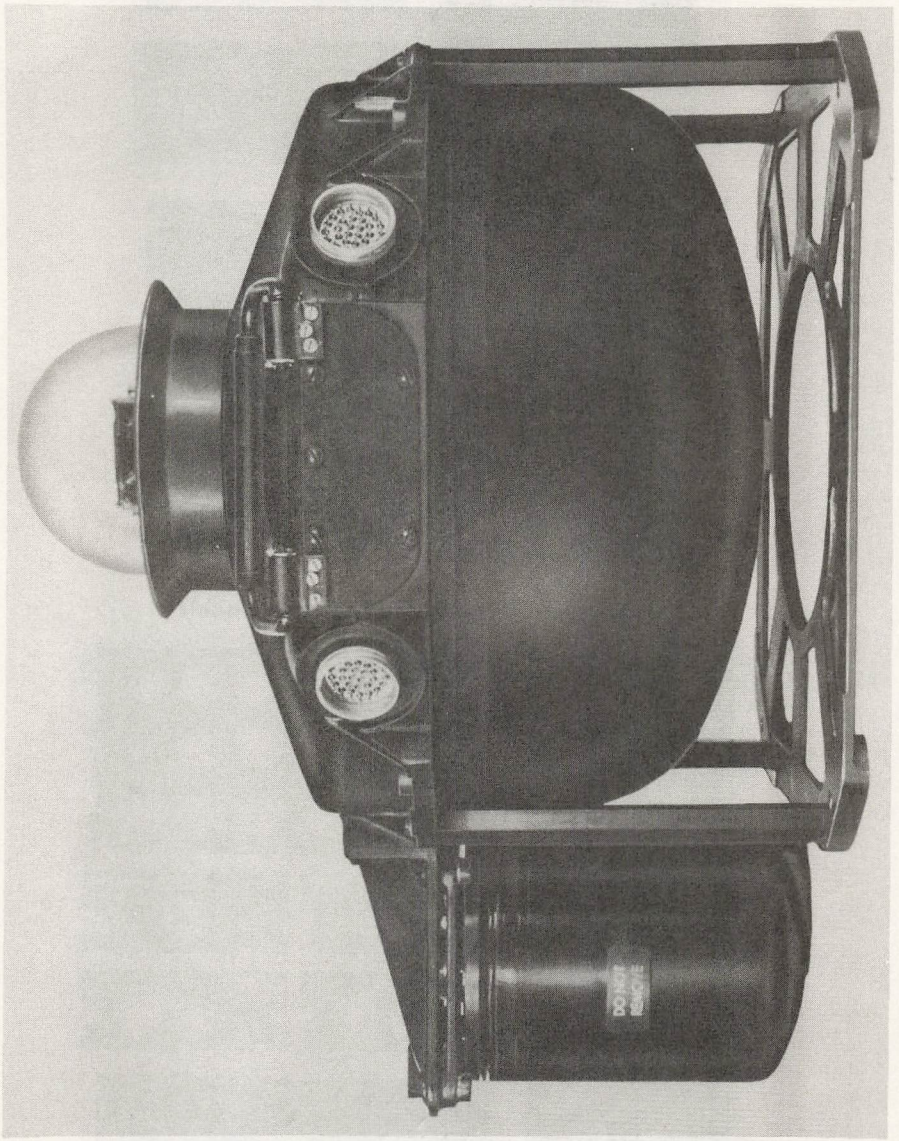

Figure 1-1. Astro Tracker

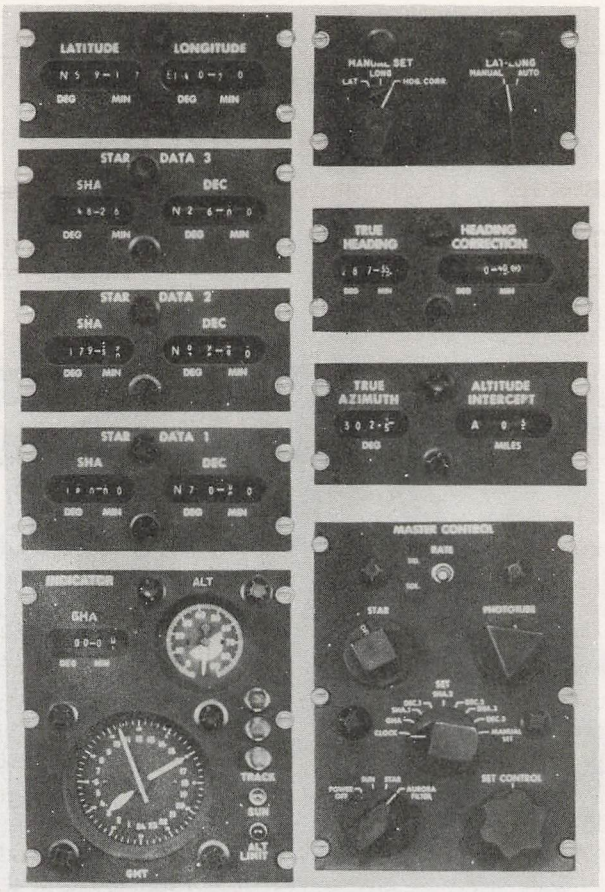

Figure 1-2. Control and Indicator Panels

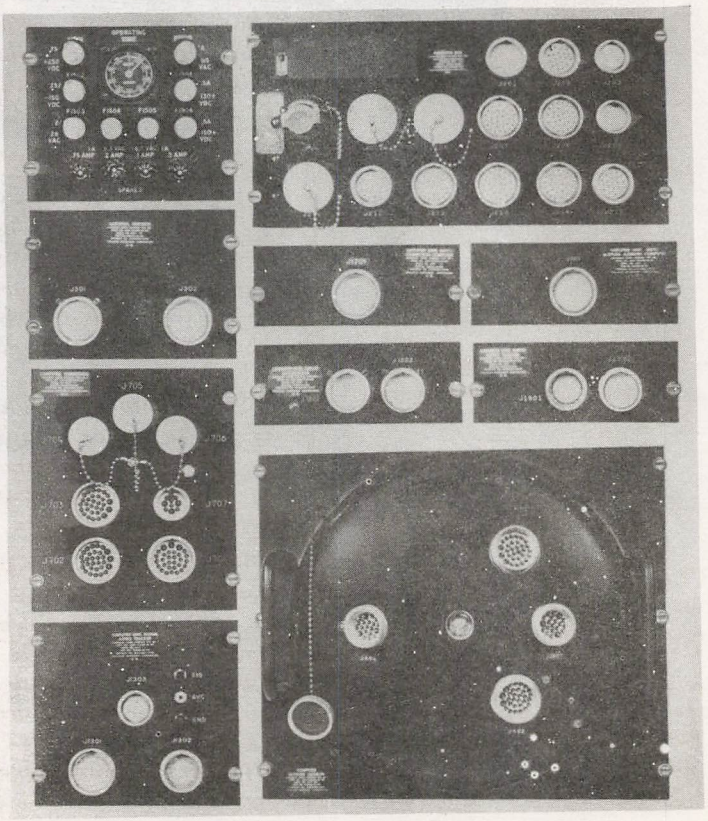

Figure 1-3. Amplifier and Computer Components

SECTION I.
GENERAL DESCRIPTION

1-1. PURPOSE OF HANDBOOK.

1-2. This handbook describes the theory of operation, operating procedures and emergency operation for the Automatic Astro Compass, Kollsman part number KS-50-03, Air Force type number MD-1, manufactured by the Kollsman Instrument Corporation, Elmhurst, New York. Figures 1-1, 1-2 and 1-3 show the units that compose the system.

1-3. PURPOSE OF EQUIPMENT.

1-4. The Automatic Astro Compass is an electro-mechanical airborne device which produces a true heading reference accurate to within a rms error of six minutes of arc. Its reference is celestial and therefore independent of the earth's magnetic field. Its ability to lock on and continuously track a selected celestial body produces continuous heading as electrical servo information or as a visual reference displayed on a counter. In addition, the system computes and displays true azimuth, celestial altitude, altitude intercept and heading correction (i.e. the difference between magnetically generated heading and Astro heading).

1-5. To accomplish this function the system accepts information describing the aircraft's geographic position, the sidereal position of the selected celestial body, the relative position of the sidereal coordinate system to the geographic (GHA) and a preliminary heading reference (best available true heading).

1-6. GENERAL DESCRIPTION.

1-7. FUNCTIONAL DESCRIPTION.

1-8. Applied inputs described in paragraph 1-5 (latitude, longitude, sidereal hour angle, declination, Greenwich hour angle and best available true heading) are utilized by the system to compute a preliminary line of sight to the celestial body in terms of altitude and relative bearing. This information serves to position a tracking device so that it looks at the general area of the sky which includes the selected body. The tracker then locates, locks on, and continuously tracks that body. Once tracking, the system evaluates observed information against computed and transmits corrected true heading computed on the basis of the measured errors in best available true heading.

1-9. PHYSICAL DESCRIPTION.

1-10. The MD-1 system consists of twenty separate components divided into three type groups. The first comprises the control and indicator units which must be located so that they are convenient and visible to the operator. Figure 1-2 is an illustration of this group. Of the nine packages in this group, two contain all of the controls required for operation of the system, five display input data, and two display computed or measured output data. Except for the control panels, all of the packages in this group are hermetically sealed and filled with dry nitrogen to reduce the probability of corrosion.

1-11. The second group of ten components (see figure 1-3) contains those that may be remotely located from the operator's position in any convenient area of the aircraft subject only to restrictions in the lengths of interconnecting cabling. This group consists of the electronic power supply and amplifier units and the mechanical computer units. There are two computer components which are hermetically sealed and filled with dry nitrogen, seven amplifier and power racks which are not sealed but contain individually sealed amplifier and power packages, and the tenth component, the junction box through which most of the system's data passes, thus providing a convenient test area.

1-12. The tracker is grouped by itself since its location and alignment are critical. The tracker is located at the top of the aircraft close to the longitudinal axis. Fore-aft alignment of the tracker must be parallel to the longitudinal axis of the aircraft as determined by the composite bombing and navigational systems, and vertical positioning will correspond as closely as possible to the normal flight attitude of the aircraft. This is basically a mechanical unit an is therefore sealed and filled with dry nitrogen. (See figure 1-1.)

1-13. SYSTEM COMPONENTS.

1-14. The MD-1 Automatic Astro Compass consists of twenty component packages. Except for the Astro Tracker, these components are designed to fit into standard Air Force module type racks. Similar or related functions are enclosed in separate components and the components are completely interchangeable with similar replacement units. This arrangement provides simplified trouble isolation and flexible line maintenance. The following paragraphs provide a brief description of the individual components. Table I is a tabulation of the separate components by name and government stock designation.

1-15. MASTER CONTROL PANEL (see figure 1-4). This unit provides six of eight control functions required to operate the system. Power and type of body selected (sun or star) are selected by the power off-filter switch (not designated). Manual input setting is selected for a specific function by the SET switch and controlled by the SET CONTROL switch. The SET CONTROL is a potentiometer with a sprung to center-off position and controls rate as well as direction of the selected counter.

TABLE I

AUTOMATIC ASTRO COMPASS, TYPE MD-1 SYSTEM COMPONENTS

QUANTITY MINIMUM	ITEM	AIR FORCE STOCK NUMBER
1	Altitude-Azimuth Computer	6225 A26960 00 001
1	Correction Computer	6225 A26970 00 001
1	Astro-Tracker	6225 B21550 00 001
1	Indicator Display Panel	6225 B23090 00 001
1	Star Data Display Panel No. 1	6225 A21570 00 001
1	Star Data Display Panel No. 2	6225 A21570 00 002
1	Star Data Display Panel No. 3	6225 A21570 00 003
1	Master Control Panel	6225 A26980 00 001
1	Astro-Tracker Signal Amplifier Unit	6225 C23180 00 001
1	Astro-Tracker Servo Amplifier Unit	6225 B24220 00 001
1	Altitude-Azimuth Computer Servo Amplifier Unit	6225 B24200 00 001
1	Correction Computer Servo Amplifier Unit	6225 B24210 00 001
1	Erection Amplifier Unit	6225 B24670 00 001
1	Power Supply Unit	6225 B23200 00 001
1	Junction Box	6225 A26990 00 003
1	Manual Present Position Display Panel	6225 A23130 00 001
1	Manual Set Panel	6225 C23160 00 001
1	Line of Position Display Panel	6225 B21590 00 001
1	Accessory Servo Amplifier Unit	6225 C23170 00 001
1	Heading Display Panel	6225 C23140 00 001

1-16. Standby or one of 3 tracking positions is selected by a STAR switch, and the PHOTOTUBE switch selects one of two phototubes (which sense star light). A RATE switch selects rate of change of Greenwich hour angle to correspond to sun's rate (SUN) or Aries rate (SID).

1-17. The front panel of this component is fabricated from a lucite sheet which is painted opaque black. Lettering is engraved through the paint and illumination is provided from behind by panel lights affixed to the lucite panel.

1-18. The rear plate mounts nine connectors and two pigtails to provide interconnection between the component and the system.

1-19. INDICATOR DISPLAY PANEL (see figure 1-5). This component displays three functions and three modes of operation. A clock is provided on this panel for the convenience of the operator, and Greenwich hour angle and celestial altitude are displayed on a counter and dial. A time drive motor and gear train within the unit advance the clock and the Greenwich hour angle (GHA) counter as a function of time.

1-20. Three TRACK lights indicate tracking mode of operation for one of three selected celestial bodies. A SUN light indicates phototube protect mode which is initiated when the phototube is exposed to a damaging level of light intensity. An ALT LIMIT light indicates that the system is operating at its high or low extreme in celestial altitude.

1-21. This is a mechanical, hermetically sealed package. Dial and counter lighting is provided from the edge through the lucite front panel from panel lamps inserted from the front. Lettering is illuminated from the same source. Two connectors on the back plate provide interconnection of the component with the rest of the system.

1-22. MANUAL SET PANEL (see figure 1-6). This component contains two rotary type switches. One selects the manual (MANUAL) or automatic (AUTO) mode of operation which determines the generating point for latitude and longitude (MANUAL for internal present position and AUTO for external source). The second control selects the set mode for the three functions that are normally received as externally gen-

erated information (latitude, longitude and best available true heading). The front panel and control knobs are fabricated from lucite with markings engraved through a black opaque coating. Illumination is provided by two panel lamps extending into the panel so that lighting appears from behind the markings. Five connectors and one pigtail on the back plate provide interconnection with the rest of the system.

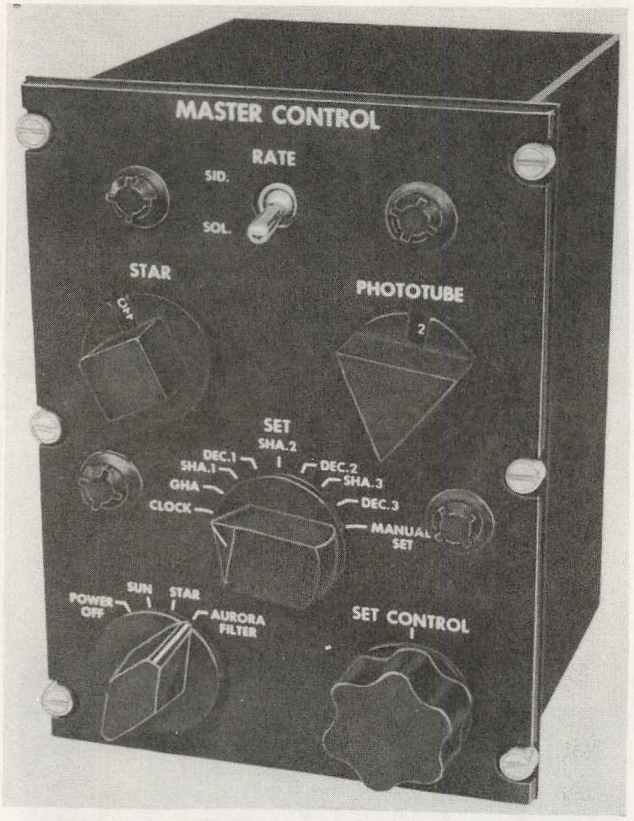

Figure 1-4. Master Control Panel

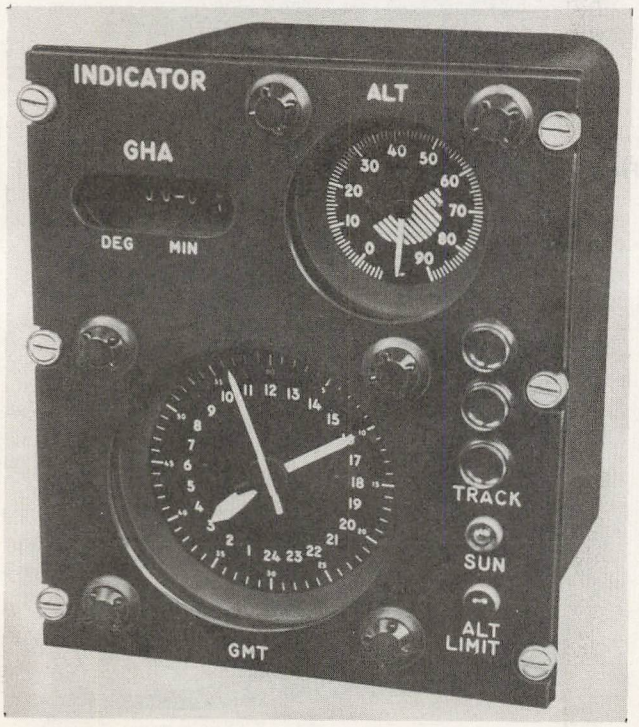

Figure 1-5. Indicator Display Panel

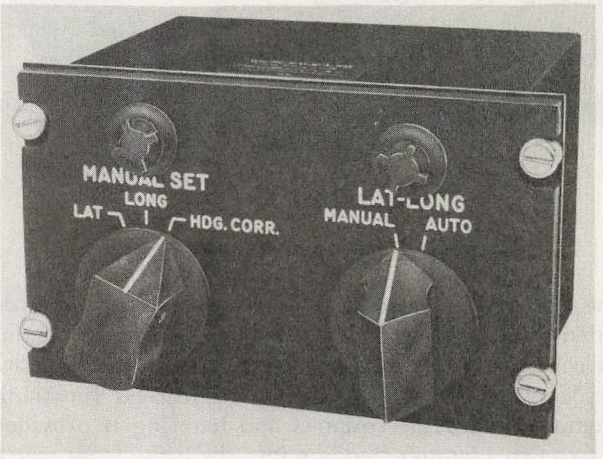

Figure 1-6. Manual Set Panel

1-23. LINE OF POSITION DISPLAY PANEL (see figure 1-7). This is a sealed, mechanical unit which displays TRUE AZIMUTH and ALTITUDE INTERCEPT to be used for line of position information. The unit contains the counters, gear trains and synchro mechanism required to receive and display these functions. Illumination for the counters and lettering is provided through a lucite front panel from two panel lamps. One connector on the back plate provides interconnection with the rest of the system.

1-24. HEADING DISPLAY PANEL (see figure 1-8). This panel displays on counters, indication for true heading (TRUE HEADING) and heading correction (HEADING CORRECTION) computed by the system.

Figure 1-7. Line of Position Display Panel

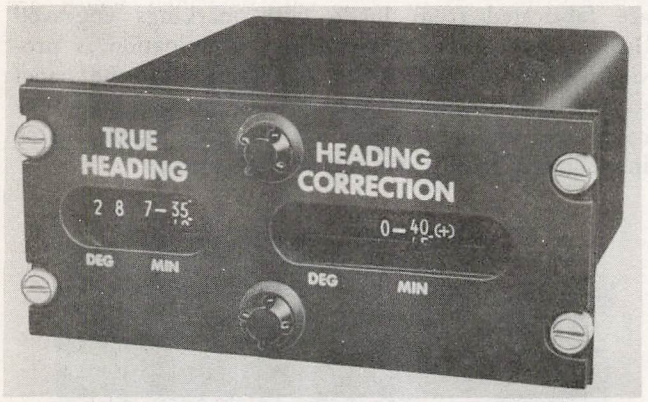

Figure 1-8. Heading Display Panel

Figure 1-9. Accessory Servo Amplifier

The package is basically mechanical and is therefore sealed and filled with dry nitrogen. The unit contains the counters, gear trains and synchro mechanisms necessary for acceptance and display of its two functions. Illumination for the counters and lettering is provided by two panel lamps extending into the lucite front panel. Interconnection with the system is provided by one connector on the back plate of the package.

1-25. ACCESSORY SERVO AMPLIFIER (see figure 1-9). Four servo amplifier pairs are housed in this component as sealed, plug-in units. A servo amplifier pair consists of a sealed pre-amplifier and a servo magnetic amplifier, both with tube type plug bases. Two Cannon type connectors on the front plate provide interconnection with the system.

1-26. The four servo loops serviced by this rack position read out counters which are not essential to the primary function of the system and are therefore deemed accessories. The functions include true heading, heading correction, true azimuth and altitude intercept, all read from counters on two display panels.

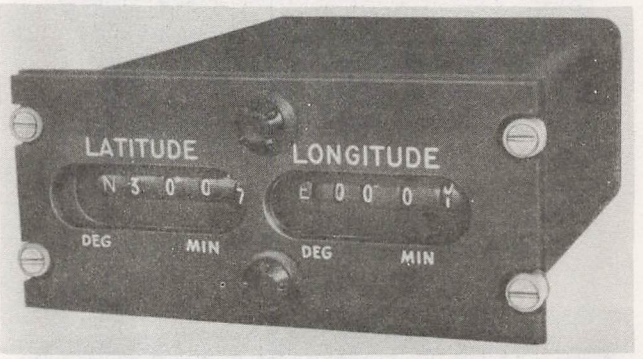

Figure 1-10. Manual Present Position Display Panel

1-27. MANUAL PRESENT POSITION DISPLAY PANEL (see figure 1-10). Displays for manually inserted latitude and longitude are presented on this panel as counter type indications. The component contains the servo mechanisms for transmitting the information, the counter for display, and associated gear trains. The component is basically mechanical and therefore sealed and filled with dry nitrogen.

1-28. Two panel lamps inserted through the lucite front cover illuminate the counters and lettering. A single connector mounted on the back plate provides interconnection with the system.

1-29. ERECTION AMPLIFIER (see figure 1-11). This is an electronic unit containing the necessary amplifiers and relays to maintain the position of the vertical reference gyro in alignment with respect to apparent gravity. Two replaceable plug-in type amplifiers mounted on the chassis are hermetically sealed. Two connectors on the front panel provide interconnection with the system.

Figure 1-11. Erection Amplifier

Figure 1-12. Star Data Display Panel (No. 1)

Figure 1-13. Star Data Display Panel (No. 2)

Figure 1-14. Star Data Display Panel (No. 3)

1-30. STAR DATA DISPLAY PANEL (see figures 1-12, 1-13 and 1-14). The MD-1 system includes three identical Star Data Display Panels which are distinguished by the numbers one, two and three on the front panel. Two counters on these panels display sidereal hour angle (SHA) and declination (DEC) which describe a star position in the celestial sphere. The counters are positioned by a set motor in accordance with input information. This is transmitted into the system from synchro mechanisms. The package contain the synchro mechanisms, counters and gear trains required for developing and transmitting this information.

1-31. The counters and lettering are illuminated by two panel lamps inset in a lucite front panel. Interconnection with the system is accomplished through a single connector mounted on the back plate of the package.

1-32. ALTITUDE AND AZIMUTH COMPUTER (see figure 1-15). The altitude and azimuth computer accepts servo type information from display panels and external equipment relative to latitude of the observer, declination of the celestial body and local hour angle between them. This serves to position three axes of a mechanical analogue type computer which recreates in miniature the conventional celestial navigational triangle. Two output axes in the computer are in turn positioned to reflect celestial altitude and true azimuth based on input information. Synchro mechanism on these axes transmit, as servo information, the computed values.

1-33. The component contains the analogue computer and the servo mechanisms and gear trains required to accept inputs and transmit computed values. A series of micro switches establish electrical limit switching to prevent damage to the analogue at its positional ex-

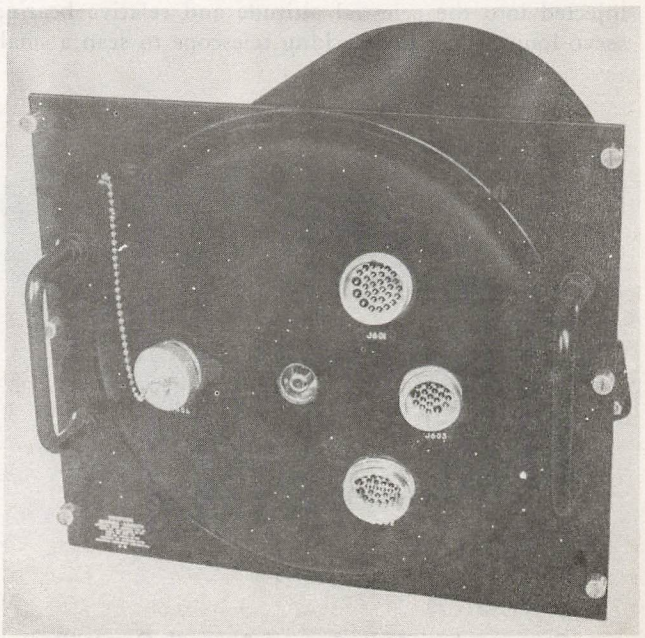

Figure 1-15. Altitude and Azimuth Computer

tremes. Hemisphere switching is also automatically performed in this component.

1-34. The container is hermetically sealed and filled with dry nitrogen to protect the mechanical portions of the component. Inputs and outputs are applied through three connectors mounted on the front of the container and one additional connector provides a test point.

1-35. ALTITUDE AND AZIMUTH COMPUTER SERVO AMPLIFIER (see figure 1-16). This component contains the three servo amplifier pairs that drive the input functions of the Altitude and Azimuth Computer (latitude, declination and local hour angle). The three amplifier pairs (six units) are themselves hermetically sealed and plug in to tube type bases in the amplifier rack. A single connector mounted on the front panel provides interconnection with the system.

1-36. CORRECTION COMPUTER (see figure 1-17). Housed in this component are the mechanisms and three gear trains which serve the following functions.

a. The heading gear train with its synchro mechanisms accepts best available true heading (BATH), heading correction and star azimuth. From this information the gear train and servos compute and electrically transmit relative bearing which positions the tracking telescope, and true heading and heading correction as outputs to counters and to external equipment.

b. The altitude gear train with its associated synchro mechanisms accepts, as servo information, computed celestial altitude and altitude correction. Synchro mechanisms then transmit corrected or observed celestial altitude to position the tracking telescope, and altitude intercept for counter display.

c. The search gear train is composed of a series of mechanisms which develop electrical signals which when injected into the celestial altitude and relative bearing servo loops, cause the tracking telescope to scan a small

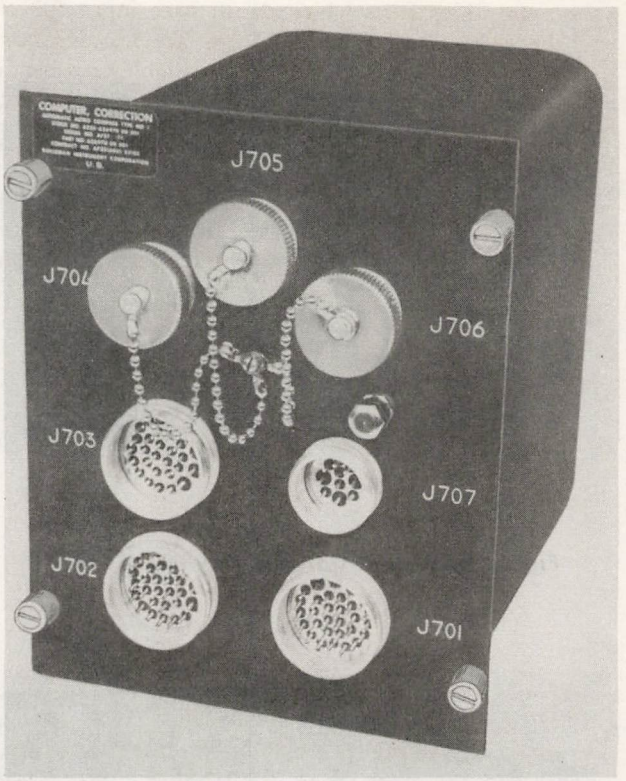

Figure 1-17. Correction Computer

area of the sky in a spiral pattern until a celestial body is sighted. When a body is recognized, the search pattern is automatically discontinued.

1-37. The correction computer which performs these functions is an hermetically sealed component and is filled with dry nitrogen to prevent corrosion of the enclosed mechanical units. Seven connectors on the front panel provide interconnection with the system.

1-38. CORRECTION COMPUTER SERVO AMPLIFIER (see figure 1-18). This component contains three

Figure 1-16. Altitude and Azimuth Computer Servo Amplifier

Figure 1-18. Correction Computer Servo Amplifier

servo amplifier pairs which drive three input functions to the correction computer. These are heading correction, altitude correction and best available true heading. The three amplifier pairs consist of six hermetically sealed plug-in units mounted on the amplifier rack. A single connector mounted on the front panel provides interconnection with the system.

1-39. ASTRO TRACKER (see figure 1-1). Contained in the Astro Tracker are a tracking telescope and a stable platform to maintain the tracking telescope in a vertical position. A vertical reference gyro is mounted on the outside of the Astro Tracker and provides vertical reference information for the stable platform servo drives. The system is sealed and filled with dry nitrogen to protect the optics in the telescope and the mechanical gear trains from corrosion and deterioration.

1-40. A hemispherical glass dome is mounted at the top center of the Astro Tracker housing through which light is admitted to the tracking telescope. The tracking telescope extends up into the dome so that its two axes of motion, celestial altitude and relative bearing, and its optical center line intersect at the optical and geometric center of the dome. The pitch and roll axes of the stable platform also intersect at this point.

1-41. The tracking telescope (see figure 1-19) is an optical device which accepts and detects light from a celestial body. A ninety degree prism which is free to rotate in relative bearing and angular altitude is mounted at the top of the tracking telescope and serves to direct light, passing in through the dome, vertically downward along the optical axis of the telescope. Condensing lenses project and focus the light to a point in the telescope. At the point of focus two rotating, mechanical units (shutter and raster) intercept and modulate the light signal which is then directed horizontally by a fixed ninety degree prism into a photo-electric multiplier tube which converts the light signal into electrical information. A second phototube, mounted at the bottom of the telescope, may be selected by rotating the fixed prism so as to look into the second tube. Two removable filters in the optical path provide for tracking under a variety of conditions.

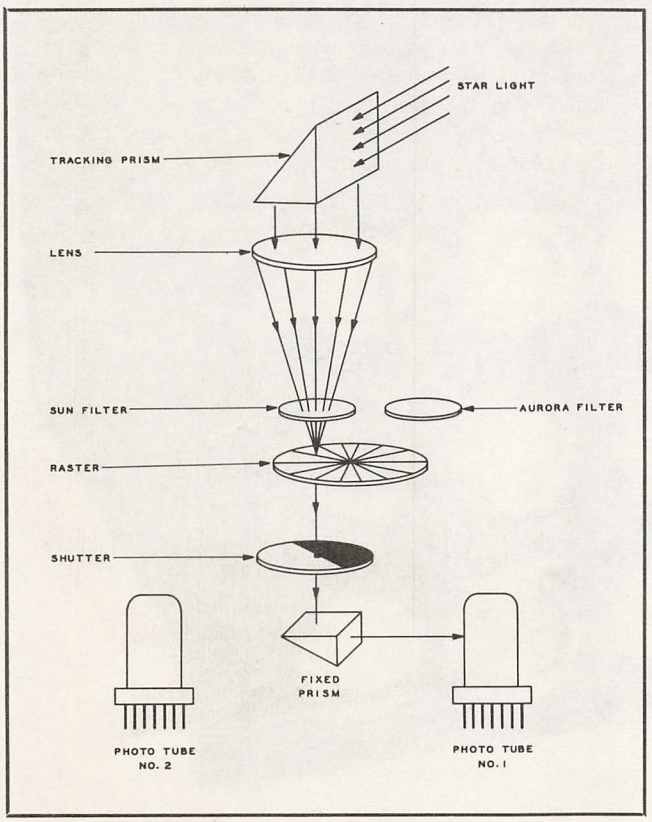

Figure 1-19. Tracking Telescope

Figure 1-20. Astro Tracker Servo Amplifier

1-42. The tracking telescope is mounted on the stable platform which is free to move in pitch and roll so the telescope is vertical regardless of the position of the tracker package within platform limits of fifteen degrees in pitch and roll from the vertical. The platform consists of two pairs of circular rails the curvatures of which are centered in an axis passing through the point of intersection of the optical axes of the system. One pair of these rails are oriented along the pitch axis of the Astro Tracker and carry the tracking telescope. The second pair are oriented along the roll axis and carry the pitch rails and the tracking telescope. The telescope is driven to its vertical position along these rails by motors mounted on the telescope. Vertical reference is provided to these motors as servo information from the vertical gyro mounted externally on the Astro Tracker.

1-43. ASTRO TRACKER SERVO AMPLIFIER (see figure 1-20). This component mounts four pairs of servo amplifier units which control the four input functions of the Astro Tracker (celestial altitude, relative bearing, pitch and roll). The four amplifier pairs consist of eight hermetically sealed, plug-in units which fit into tube type receptacles mounted on the amplifier rack. Two connectors mounted at the front of the component provide interconnection with the system.

1-44. ASTRO TRACKER SIGNAL AMPLIFIER (see figure 1-21). This component mounts eight hermetically sealed amplifier and power supply units. The units and their functions follow.

a. The Celestial Signal Amplifier receives celestial body information from the Astro Tracker and performs three functions. It detects the presence of a celestial body in the Tracker's field of view and initiates "star recognition" mode. It modifies, amplifies and transmits an "error" signal based on the signal from the Astro Tracker indicating that the celestial body image is not in the center of the telescope's field of view. It detects overload signals from the photo multiplier tube and initiates a protect mode to prevent damage to the tube.

b. The altitude demodulator-modulator and the relative bearing demodulator-modulator receive the error signal developed in the celestial signal amplifier. By comparing this signal with electrical reference, they detect altitude or relative bearing components of the total error signal. The units then remodulates the respective errors to a usable servo signal with which to drive correction functions.

c. The altitude and relative bearing correction preamplifier separately processes the correction signals developed in the demodulator-modulators to produce more acceptable servo signals with respect to wave shape and current.

d. The tuning fork provides frequency standard at 500 cycles per second to drive those functions (Time, GHA, shutter-raster) which require precision rates.

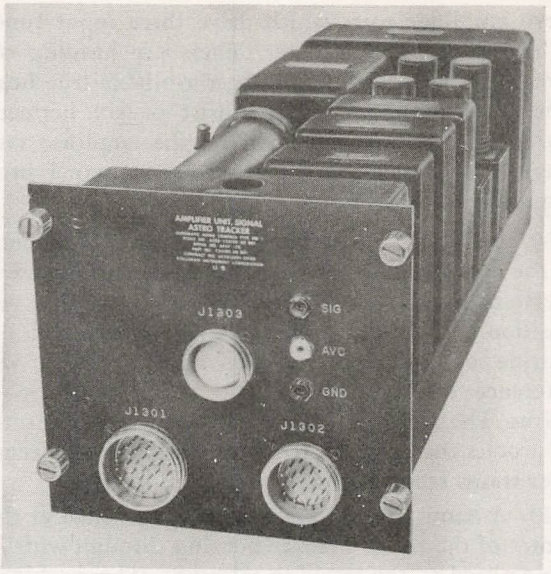

Figure 1-21. Astro Tracker Signal Amplifier

e. The time standard amplifier reduces the 500 cycles per second frequency from the tuning fork to the precise 250 cycles per second frequency required for the time drive motors.

f. The 250 cycle per second power amplifier accepts

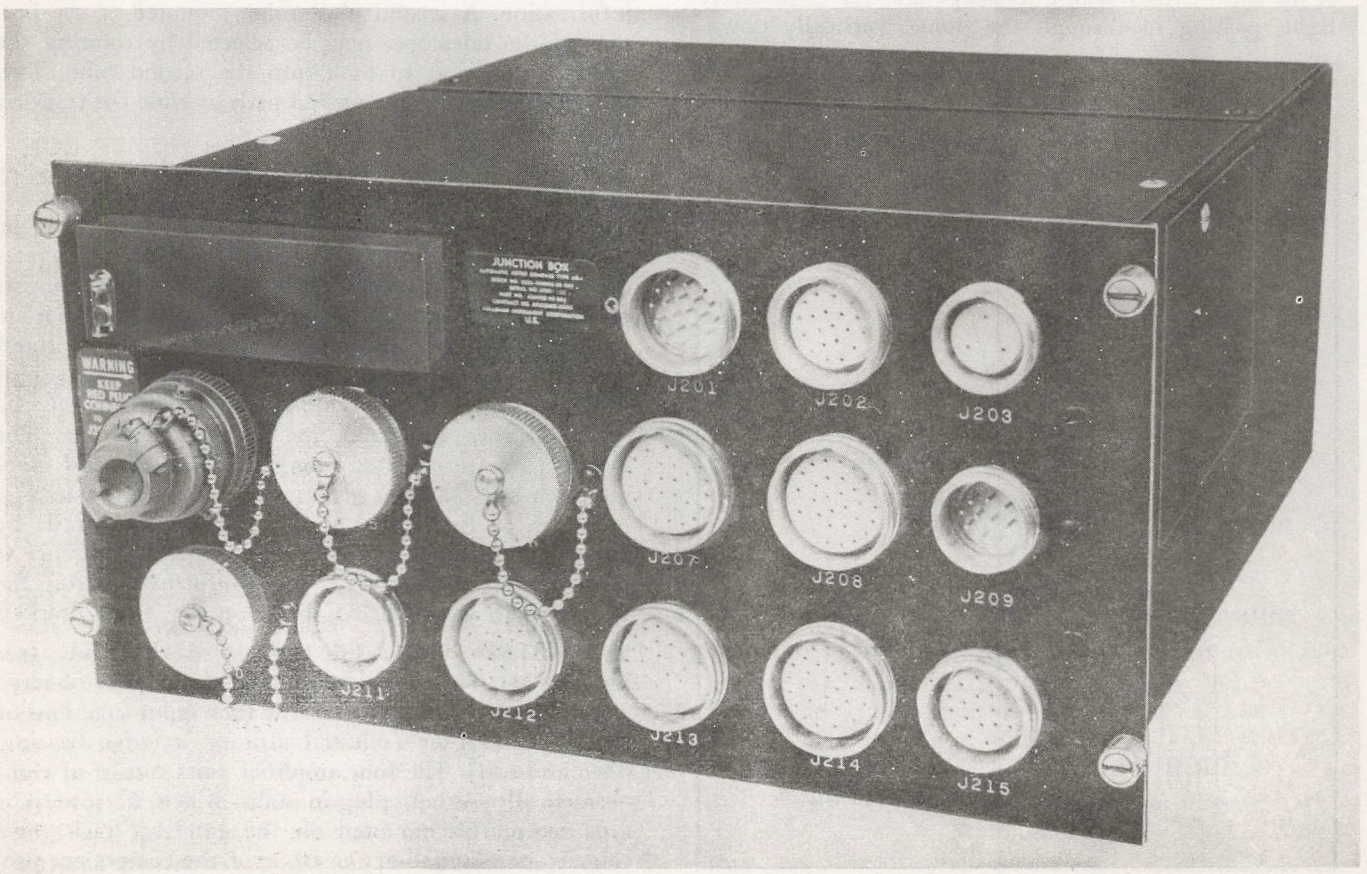

Figure 1-22. Junction Box

the output from the time standard amplifier and increases power to an adequate level to drive the time motors.

g. The minus 900 volt power supply generates photomultiplier tube power.

1-45. JUNCTION BOX (see figure 1-22). This component provides a meeting point for most of the interconnecting cabling in the system. This provides simplified cabling and a central testing area. Thirty-three connectors on the front and back plates of the box provide interconnection and test connections. Five screwdriver adjustments for pitch and roll trim, altitude and relative bearing correction gain, and true heading index error adjustment are mounted on, and accessible from the front plate.

1-46. POWER SUPPLY (see figure 1-23). This component accepts aircraft power and produces and distributes the electrical power required by the various functions of the system. System fusing is located on the front panel of this package and an elapsed time clock indicates number of operating hours on the system. A single connector provides interconnection with the rest of the system.

Figure 1-23. Power Supply

1-47. THEORY OF OPERATION.

1-48. Inputs for Greenwich hour angle of the sun, planet, or Aries, sidereal hour angle of the celestial body (zero for sun and planets), and declination of the body, are applied manually through a slewing potentiometer to position synchro mechanisms and counters. Latitude and longitude may be applied manually or accepted from an external navigational computer. Best available true heading (BATH) is accepted from an external source based on magnetic heading reference. Based on this initial input information, the system computes a preliminary line of sight to a selected celestial body and a tracking telescope is directed along this line of sight so that the body will be located near the telescope's area of vision. The telescope will then search that area of the sky in an expanding spiral pattern until it locates the celestial body at which time a star presence mode of operation commences. Positional error between the computed line of sight and the actual location of the body is measured and divided into component errors in angular altitude and relative bearing. Errors are applied back to the computed line of sight as a correction where altitude error becomes altitude intercept and relative bearing becomes true heading correction. Based on a corrected line of sight, the tracker is repositioned so that the star image falls precisely on the center of the telescope's field of view. The system is now tracking since any displacement of the body from the center of the telescope's field of view will cause an error signal which will be applied to correct the line of sight.

1-49. Finally, the heading correction signal, which represents error in best available true heading, is mechanically added to that function to produce a shaft position indicative of corrected heading or true heading. Synchro mechanisms then transmit true heading as the primary system output to external equipment. In addition, true heading correction is provided as an external output and altitude intercept, true azimuth, true heading and heading correction serve to position counters for visual display. The following paragraphs are a description of the system functions which produce the required information.

1-50. BLOCK DIAGRAM. (see figure 1-24).

1-51. All set information originates at the SET CONTROL on the Master Control Panel and is distributed to the various function counters and gear trains through the SET switch. Sidereal hour angle (SHA) and declination (DEC) are applied to three star data display panels and serve to position counters for visual reference and synchro mechanisms for transmittal of that information. Declination is transmitted as an input to the altitude and azimuth computer, while sidereal hour angle is added to servo input information for local hour angle of the sun or Aries and is transmitted to the altitude and azimuth computer as local hour angle (GHA —LONG +SHA) of the sun (SHA = ZERO) or star. Greenwich hour angle (GHA) of the sun or Aries is applied from the Master Control Panel to a counter and synchro mechanism in the INDICATOR Display Panel. At this point longitude is accepted from the Manual Present Position Display Panel or from an external source, at the option of the operator, as servo information and, measured westward, is subtracted from GHA. The output is GHA minus west longitude or LHA of the sun or Aries which is transmitted to the Star Data Display panels where it is added to SHA. As manual or internal functions, latitude and longitude are set by the SET CONTROL in the Master Control Panel. Function control is applied through the Manual Set Panel at the MANUAL SET switch and to the

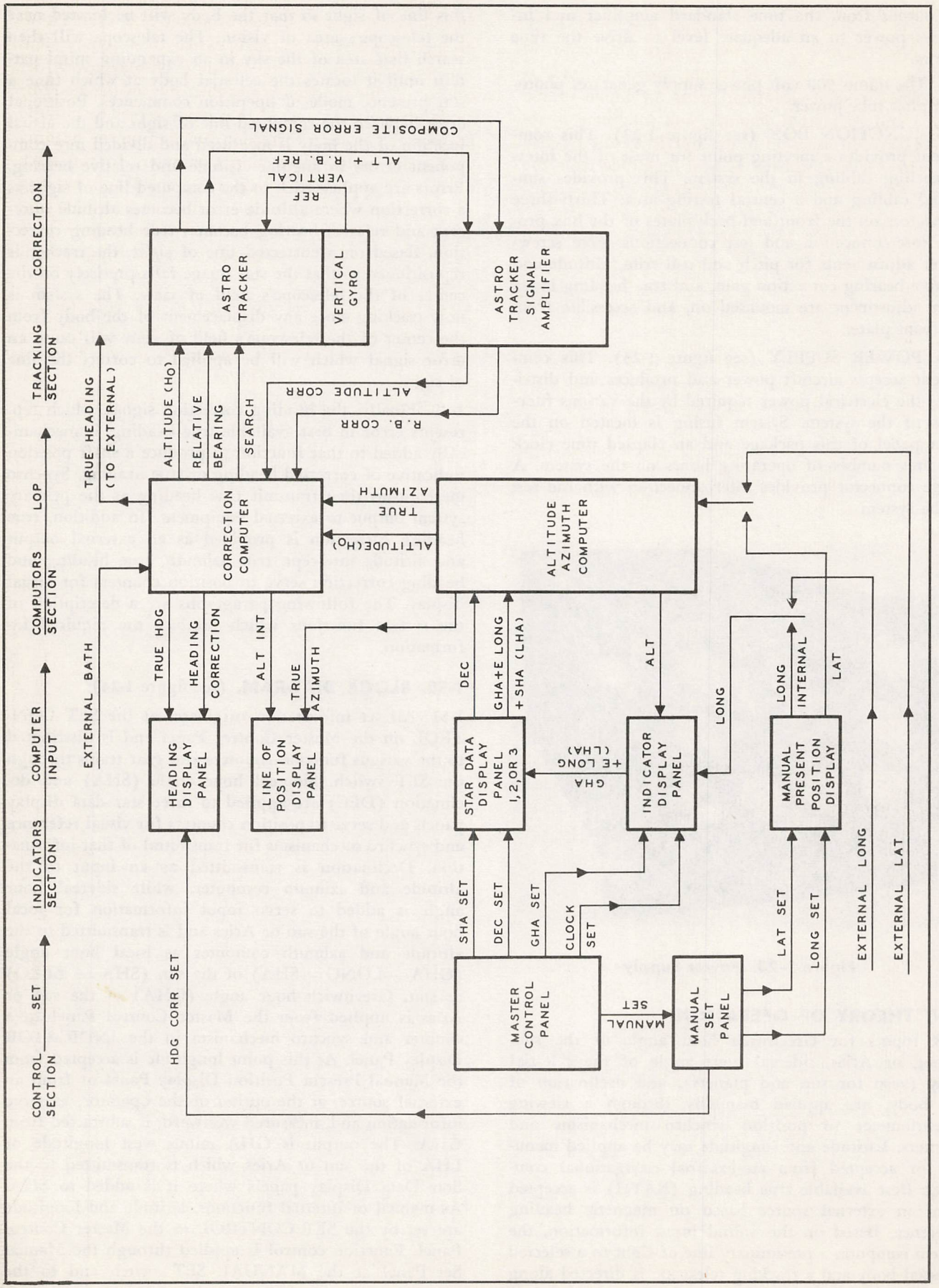

Figure 1-24. Block Diagram

separate function in the Manual Present Position Display Panel. Set information positions the LATITUDE and LONGITUDE counters and synchro mechanism in the Manual Present Position Display panel. Latitude is transmitted as servo information as an input to the Altitude and Azimuth Computer, and longitude is applied as servo information to the INDICATOR Display panel where it is subtracted as west longitude from the GHA developed in that panel. As automatic functions, latitude and longitude are accepted as servo information from some external source. Latitude is applied to the Altitude and Azimuth Computer and bypasses the display panel. Longitude is applied to GHA in the Indicator Display Panel and also bypasses the Manual Present Position Display panel.

1-52. Greenwich mean time (GMT) is set from the SET CONTROL and positions a clock in the INDICATOR Display Panel. The clock provides time reference for the operator, but is not a function within the system. Heading correction is applied from the SET CONTROL through the MANUAL SET switch to a counter and synchro mechanism in the Heading Display panel. Set control of this function is possible only in the stand-by mode of operation and in that mode serves to initially position the heading correction function on the heading gear train in the Correction Computer. In the track mode of operation the loop is reversed and heading correction is computed in the Correction Computer and transmitted as servo information to the counter as a visual indication of measured or actual heading correction.

1-53. Three inputs are presented to the Altitude and Azimuth computers from the indicator and display panels and from external equipment in the form of servo signals. These are LHA of the sun or star, declination of the sun or star, and observers latitude. These

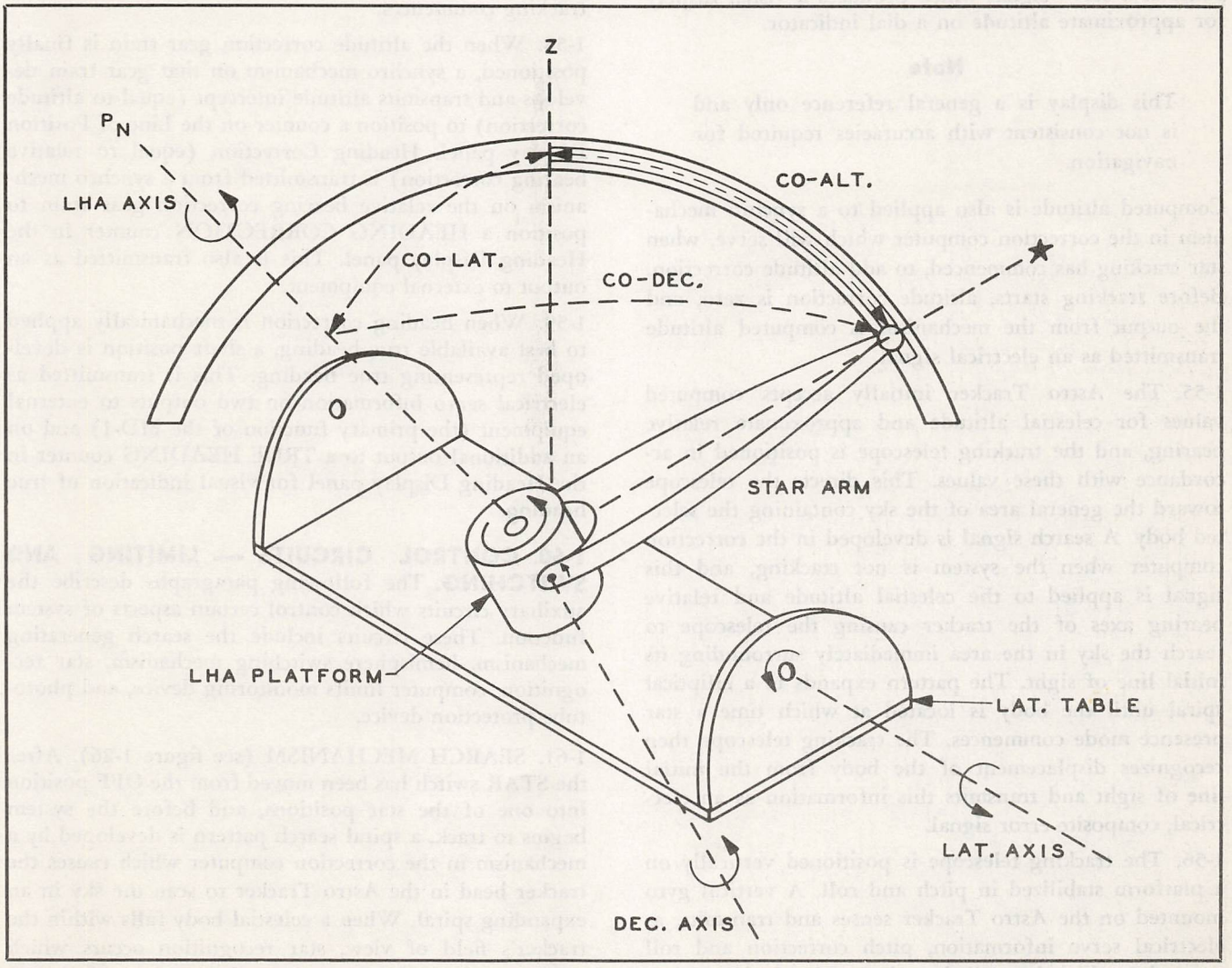

Figure 1-25. Analogue Computer

servo signals are applied to synchro mechanism, which position three corresponding axes on a mechanical analogue computer. Once positioned, the computer develops shaft positions on two output gear trains which represent celestial altitude and azimuth (see figure 1-25). These gear trains in turn position synchro mechanism which transmit computed altitude and true azimuth as servo signals. True azimuth is fed to the Line of Position Display Panel where a counter displays this information for visual reference. True azimuth is also fed to the Correction Computer where it is applied electrically to a synchro mechanism which subtracts best available true heading (BATH). Best available true heading is accepted by the correction computer as a servo signal from an external source, and this signal serves to position a gear train and mechanism which subtracts BATH from azimuth providing a resulting servo output for approximate relative bearing.

1-54. Computed altitude developed in the Altitude and Azimuth Computer is fed to the INDICATOR Display panel as a servo signal which produces a visual display for approximate altitude on a dial indicator.

Note

This display is a general reference only and is not consistent with accuracies required for navigation.

Computed altitude is also applied to a synchro mechanism in the correction computer which will serve, when star tracking has commenced, to add altitude correction. Before tracking starts, altitude correction is zero, and the output from the mechanism is computed altitude transmitted as an electrical signal.

1-55. The Astro Tracker initially accepts computed values for celestial altitude and approximate relative bearing, and the tracking telescope is positioned in accordance with these values. This directs the telescope toward the general area of the sky containing the selected body. A search signal is developed in the correction computer when the system is not tracking, and this signal is applied to the celestial altitude and relative bearing axes of the tracker causing the telescope to search the sky in the area immediately surrounding its initial line of sight. The pattern expands in a elliptical spiral until the body is located at which time a star presence mode commences. The tracking telescope then recognizes displacement of the body from the initial line of sight and transmits this information as an electrical, composite error signal.

1-56. The tracking telescope is positioned vertically on a platform stabilized in pitch and roll. A vertical gyro mounted on the Astro Tracker senses and transmits, as electrical servo information, pitch correction and roll correction which is applied to the stable platform pitch and roll axes maintaining the telescope in a vertical position regardless of aircraft attitude.

Note

Pitch and roll correction is limited to fifteen degrees along both axes.

1-57. The Astro Tracker Signal Amplifier receives the composite error signal from the Astro Tracker along with altitude and relative bearing reference signals which also originate in the Tracker. This component matches the composite error against the reference signals, extracting altitude and relative bearing components of the composite signal, and transmits electrical correction signals for those two functions. The altitude correction signal and the relative bearing correction signal are then fed back to their respective correction gear trains in the correction computer where these corrections advance shaft positions on synchro mechanism to add correction to computed and approximate values. The outputs to the Tracker from the Correction Computer then become actual values and the tracking telescope is directed precisely to the celestial body. The search output from the Correction Computer is discontinued when tracking commences.

1-58. When the altitude correction gear train is finally positioned, a synchro mechanism on that gear train develops and transmits altitude intercept (equal to altitude correction) to position a counter on the Line of Position Display panel. Heading Correction (equal to relative bearing correction) is transmitted from a synchro mechanism on the relative bearing correction gear train to position a HEADING CORRECTION counter in the Heading Display panel. This is also transmitted as an output to external equipment.

1-59. When heading correction is mechanically applied to best available true heading, a shaft position is developed representing true heading. This is transmitted as electrical servo information on two outputs to external equipment (the primary function of the MD-1) and on an additional output to a TRUE HEADING counter in the Heading Display panel for visual indication of true heading.

1-60. CONTROL CIRCUITS — LIMITING AND SWITCHING. The following paragraphs describe the auxiliary circuits which control certain aspects of system function. These circuits include the search generating mechanism, hemisphere switching mechanism, star recognition, computer limits monitoring device, and phototube protection device.

1-61. SEARCH MECHANISM (see figure 1-26). After the STAR switch has been moved from the OFF position into one of the star positions, and before the system begins to track, a spiral search pattern is developed by a mechanism in the correction computer which causes the tracker head in the Astro Tracker to scan the sky in an expanding spiral. When a celestial body falls within the tracker's field of view, star recognition occurs which causes search operation to stop and the pattern to degenerate slowly to zero. The spiral pattern is essentially an expanding circle developed on the altitude and relative

bearing axes of the tracking telescope. This circular displacement is developed by the output of a rotating synchro resolver. The angle of displacement of the tracker is a function of the angular position of the resolver while the ampltidue of displacement is a function of the input signal to the resolver. That is, as the resolver rotates through 360° the tracker will search through 360° of a small circle around it's starting point or computed line of sight, and as the excitation voltage on the resolver increases, the radius of the search circle will increase and if the two advance as linear functions, the resultant pattern will be a spiral.

1-62. However, with a given angular velocity for search (i.e. rotational speed of the resolver) as the radius increases the linear velocity along the search path increases and the tracker sweeps along the sky more rapidly. At the outer extremes of the search pattern the tracker would be sweeping at a rate such that a celestial body would appear and pass out of the field of view before the system could accomplish star recognition which would ordinarily stop search. Therefore, as the search pattern increases in radius, angular velocity is reduced so as to maintain a more or less constant sweep speed. Angular velocity of the search resolver and therefore the search pattern is controlled by a search motor. Motor speed is reduced in four steps through the search cycle by a stepping switch on the search gear train.

1-63. (See figure 1-26.) The search mechanism located in the Correction Computer consists of a motor and gear train which drive a circular potentiometer, a four step circular switch and through a clutch, a resolver. When search is initiated, a voltage is applied to the motor and to the clutch. The motor starts running and the clutch closes. As the motor turns, the resolver rotates and transmits a circular signal to the Astor Tracker. Signal into the resolver is controlled by the potentiometer on the gear train and as the potentiometer advances, signal into, and therefore out of, the resolver increases, thus increasing the radius of the search circle. The resolver and potentiometer are geared in a ratio of eight to one and the resolver will transmit eight spires of increasing radius. At the end of eight spires the potentiometer is back at it's starting point and the search cycle is complete. The radius reduces to zero and begins again to increase for another eight spires. Motor speed is controlled by the motor stepping switch. This switch rotates once for each search cycle and is in four segments. As the switch advances from one segment to the next (two search spires to a segment) a fixed resistance is injected into the motor control signal which slows the motor and rotational speed of the resolver. At the end of eight spires (one search cycle) the switch is at its starting point and motor speed increases to its starting value.

1-64. When a celestial body appears in the field of view, star recognition occurs and the search mode terminates. The search clutch opens removing drive to the resolver and the resolver stops. The search motor is caused to drive slowly in the opposite direction causing the search potentiometer to move toward its starting point in reverse. This causes the radius of search displacement to slowly reduce to zero. When the search mechanism has returned to its starting position, motor control is removed and the mechanism stops.

1-65. HEMISPHERE SWITCHING (see figure 1-27). Because of mechanical limitations the analogue unit in the Altitude and Azimuth Computer has an operational range of a single hemisphere (i.e. North or South). But, since system range is the full sphere, an arrangement must be made to provide switching to identify the hemisphere of the computer with the system's operating hemispere or latitude. This switching arrangement is automatic.

1-66. When the aircraft carrying the Astro Compass crosses the equator from one hemisphere to another,

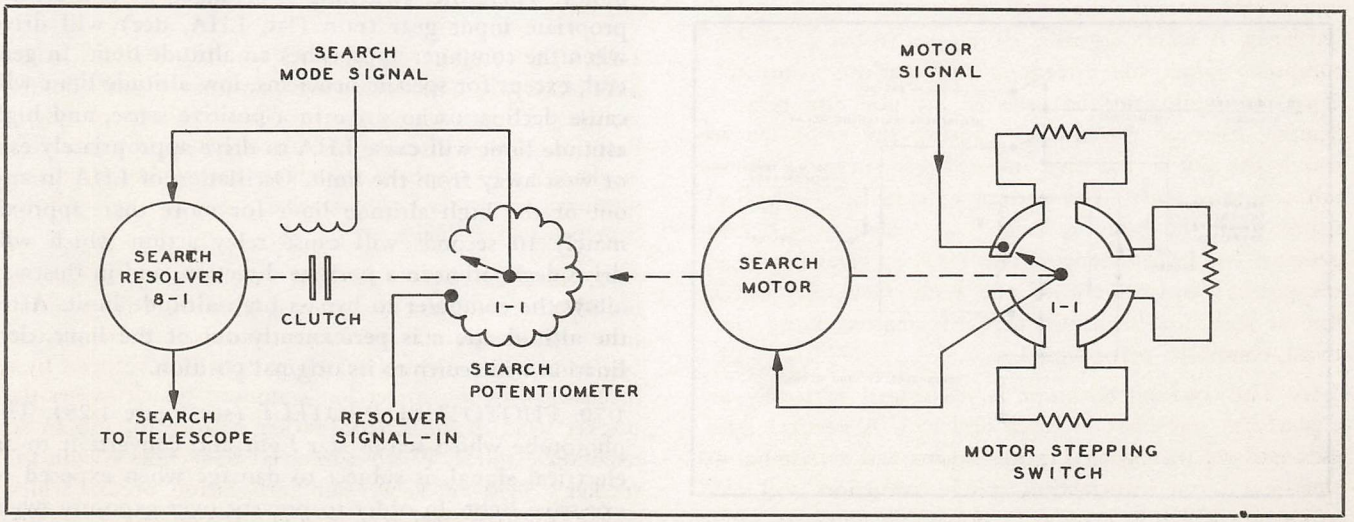

Figure 1-26. Search Mechanism

the electrical identification of the polar axis of the analogue unit is changed accordingly. North becomes south and east becomes west. When this switching occurs, the input axes of the computer (latitude, declination and local angle) are reversed in direction and appropriate electrical rearrangement must be made to accommodate this reverse. Identification of north or south hemisphere operation is determined by the position of relays which provide this electrical rearrangement. Therefore, the function of the hemishpere switching mechanism is to energize hemisphere relays for south hemisphere operation and to deenergize these relays for north hemisphre operation. The following paragraph is a description of this mechanism.

1-67. Figure 1-27 shows the hemishpere switching mechanism in northern hemisphere operation. When the aircraft crosses the equator from the northern hemisphere to thirty minutes south (or minus) latitude, the latitude gear train in the computer will activate microswitch "A" driving it to the lower contact. This will apply 28VDC to relay "B" through relay "C" causing the contacts on relay "B" to close. This provides 28VDC to energize the hemisphere relays through the upper switch on relay "B". When the hemisphere relays are energized the computer becomes the southern hemisphere and the latitude gear train drives from thirty minutes minus latitude to thirty minutes plus latitude since north is now minus. This causes microswitch "A" to be released and returned to the upper contact. Twenty eight volts is applied through the upper contact of microswitch "A", through the, now closed, lower switch of relay "B" which causes relay "B" to hold itself energized and energizes relay "C". This completes a switching cycle. When the aircraft recrosses the equator and proceeds to 30 minutes north (minus) latitude, mircroswitch "A" will again be activated to the down position. This applies 28VDC through the lower contact of relay "C" (energized previously through relay "B") to hold relay "C" energized. The dc signal will not pass through the diode against the arrow and relay "B" deenergizes. When relay "B" deenergizes the 28VDC south hemisphere signal is cut off and the hemisphere relays deenergize. This again identifies the computer hemisphere as north and the latitude gear train will drive from minus 30 minutes to plus (now north) 30 minutes latitude and relases the microswitch "A". This removes 28VDC from relay "C" which deenergizes and completes the hemisphere switching cycle.

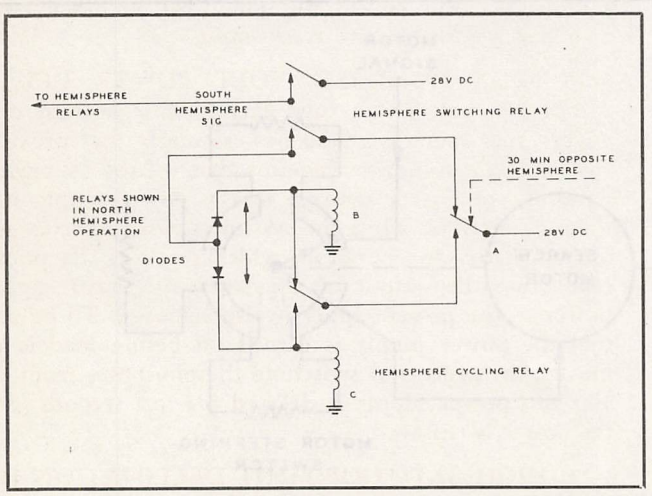

Figure 1-27. Hemisphere Switching

1-68. LIMIT SWITCHING. The analogue unit of the Altitude and Azimuth Computer is subject to mechanical limitations in latitude, declination and altitude axes. Exceeding or driving hard into these limits can cause damage or misalignment in the computer. However, a system of electrical limits activated by microswitches on the respective gear trains prevent the computer from exceeding these mechanical limits. Declination limits exist at +90° and —47° where sign is positive when declination is same name as latitude and minus when declination is opposite name. Latitude limits exist at +90° and minus 2° (approximately). However, recall that hemisphere switching occurs at minus thirty minutes so that the system will compute through 180° in latitude. Only if the hemisphere switching mechanism fails will the latitude table drive into its limit. When a latitude or declination microswitch is activated by its gear train driving to a limit, a fixed voltage from a transformer is applied to the associated motor of such a phase that the motor drives away from the limit. This action will release the microswitch and reestablish normal electrical circuitry and the gear train will drive back into the limit. Oscillation in and out of the limit will continue until set information is applied to drive the gear train permanently out of the limit.

1-69. Limits exist in altitude between minus six degrees and about 85 degrees. However, altitude is an output function and the associated gear train has no driving motor. Therefore, switching is arranged so that an appropriate input gear train (lat, LHA, dec) will drive when the computer approaches an altitude limit. In general, except for specific problems, low altitude limit will cause declination to drive in a positive sense, and high altitude limit will cause LHA to drive appropriately east or west away from the limit. Oscillation of LHA in and out of the high altitude limit for more than approximately 10 seconds will cause relay action which will drive declination in a positive direction, and in this way allow the computer to bypass high altitude limit. After the altitude train is permanently out of the limit, declination will reutrn to its original position.

1-70. PHOTOTUBE PROTECT (see figure 1-28). The phototube which senses star light and converts it to an electrical signal, is subject to damage when exposed to excessive light. In order to prevent over exposure when operating in the SUN mode, a dense optical filter is injected in the light path through the tracking telescope,

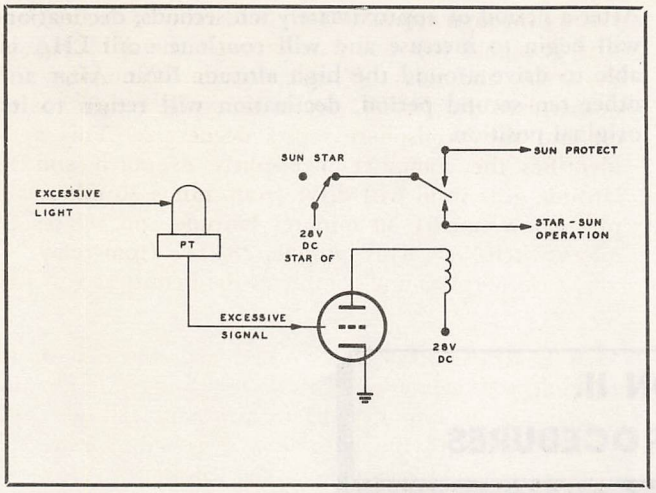

Figure 1-28. Phototube Protect

and electrical excitation on the phototube is reduced to a small value. However, because of the relatively low level of light developed by the night time celestial bodies, when operating in the STAR mode it is necessary to remove the sun filter and to increase the level of phototube excitation. This leaves the phototube vulnerable to accidental exposure to excesive light. Therefore, a circuit is incorporated in the Celestial Signal Amplifier of the Astro Tracker Signal Amplifier which detects excessive signal from the phototube indicating an excessive light, and automatically activates a mechanism (sun protect) which places the sun filter in the field of view and reduces phototube excitation.

1-71. The sun protect relay (see figure 1-28) is normally energized allowing sun or star mode of operation and the sun filter to be controlled by the "Power OFF" switch. With the "Power OFF" switch in the STAR position, a star mode signal is applied through the energized contacts of the sun protect relay to the system to establish star mode of operation. The sun protect relay coil is grounded through a normally conducting vacuum tube. So long as this tube conducts, star mode may be maintained. However, excessive signal from the phototube, indicating exposure to excessive light, will be impressed on the vacuum tube causing it to stop conducting. This opens the ground for the sun protect relay and the relay deenergizes. When the relay deenergizes, the contact carrying the star mode signal is switched and the signal is diverted causing the system to return to sun mode of operation. The diverted star mode signal is utilized to illuminate the SUN lamp on the INDICATOR Display panel and to hold the circuit in the protect position until star mode signal is turned off by placing the "Power OFF' switch in the SUN position. When this is done, the system returns to normal operation, and, if the source of excessive light has been removed, star operation may be resumed by returning the "Power OFF" switch to the STAR position.

1-72. TIME DELAY FUNCTIONS. Certain operations in the system are controlled by thermal time delay relays that activate only after a given time has elapsed after initial excitation. The functions which are delayed in the MD-1 Astro Compass are the following: 400 cycle servo motor excitation—2 minutes after power on; pitch, roll and fast gyro erection delay—seven minutes after power on; lose track search delay—fifteen seconds after losing track; phototube power switching—5 seconds after switch from star to sun operation; high altitude limit declination delay—ten seconds after engaging high altitude limit. The following paragraphs describe the purpose for these delays.

1-73. TWO MINUTE POWER DELAY. Servo motor excitation is delayed for two minutes after power is applied to the system. This serves to disable all the driving motors while the system is warming up and prevents uncontrolled drifting of the gear trains which might otherwise cause mechanical damage.

1-74. FIVE MINUTE POWER DELAY. During the first few minutes of warm-up, the vertical gyro is in the process of coming to its erect position, and in so doing goes through rapid, sweeping oscillations in pitch and roll. If the tracking telescope were to be made to follow this motion, due to the considerable weight of the telescope, the driving gear trains might be damaged. Therefore, pitch and roll information to the tracker is delayed for five minutes in addition to the two minute power delay (seven minutes in all) after application of power to allow the gyro to come approximately vertical.

1-75. FIFTEEN SECOND SEARCH DELAY. If, during tracking operation, the system loses the star and goes out of the track mode, it is usually caused by a momentary obscuration of the body being tracked. It is expected the body will reappear within a few seconds. In order to avoid having the system drop back into the search mode which may cause a complete fifty second cycle before star acquisition is reestablished, search is delayed for fifteen seconds. If the body reappears within the fifteen second period, the system will go immediately into star acquisition and track mode.

1-76. NINE HUNDRED VOLT POWER DELAY. Minus 900 volt photo tube excitation is utilized only during star operation. The power supply that provides the 900 volt excitation requires that a load be present across its output or damage to the power supply may result. Therefore, when the system is switched from star operation to sun operation, which removes the phototube from the output of the 900 volt power supply, power to the power supply is also removed. To be sure that the power supply is turned off before load is removed, the process of switching the phototube from the 900 volt power supply is delayed for five seconds after the power is removed.

1-77. HIGH ALTITUDE LIMIT DECLINATION DELAY. When the Altitude and Azimuth Computer is driven into a high altitude limit, the first corrective action is to drive the LHA gear train so that altitude

decreases which carries the computer out of the limit. Since the original signal is still present, once the computer is out of the limit LHA will drive back to its original position which will reestablish limit operation and LHA will oscillate in and out of the altitude limit. After a period of approximately ten seconds, declination will begin to increase and will continue until LHA is able to drive around the high altitude limit. After another ten second period, declination will return to its original position.

SECTION II.
OPERATING PROCEDURES

2-1. INTRODUCTION. This section will describe function of operating controls and operating procedures. Operating procedures will include preflight and inflight procedures, normal indicator displays and use of secondary functions.

2-2. CONDITIONS FOR OPERATION. Since the MD-1 is an optical tracking device, tracking ability is limited by certain "seeing" conditions which the operator must take into account when tracking function is intermittent or unattainable. For proper sun tracking it is necessary that the sun be unobscured, or, where partially obscured, that the rim or disk be clearly visible. Where a hazy overcast partially obscures the sun image, the brightly illuminated haze around the area of the sun may interfere with the tracking function when this condition is not satisfied. As a general rule which the operator may follow to determine an adequate image, if the sun's light casts a clearly defined shadow, visibility is adequate for tracking.

2-3. For star operation, two conditions must be satisfied relating to the star's apparent magnitude and to the ratio of star light intensity to the general level of illumination of the sky immediately around the star. System sensitivity is controlled so that the tracker will accept stars of approximately third magnitude or brighter. Greater sensitivity would create a broad area of ambiguity in star tracking since many non-navigational stars fall within the range of magnitude from three to the limit of vision. Lesser sensitivity would reduce the ability of the system to track polaris (magnitude 2.5 approx.) taken as the dimmest star of prime navigational importance. Therefore, it is requisite that the star to be tracked be of apparent magnitude of three or brighter keeping in mind that apparent magnitude is affected by atmospheric conditions. Where a hazy overcast is present, aparent magnitude reduces accordingly.

2-4. Regardless of star magnitude, the morning and evening twilight periods impose a second restriction on star tracking. The tracking function depends on the ability of the system to distinguish the body from the surrounding sky. During twilight periods, background light is at a sufficient level to obscure, for the tracker, all but the brightest planets. Therefore, for a period of approximately half an hour (in the middle latitudes) after sunset, tracking may be accomplished only if a very bright planet is visible. As the stars become clearly visible to the operator, generally they are visible to the tracker.

Note

Attempts to track stars in close proximity to a bright moon are not suggested since background illumination is relatively high in this area. Background illumination caused by auroral displays will be discussed in paragraph 2-11a.

2-5. MODES OF OPERATION.

2-6. System modes of operation are controlled through switches and relay action. For clarity this handbook divides the modes of operation into three areas, i.e. (operating modes, functional modes, and protective modes).

2-7. OPERATING MODES. Operating modes include those modes that are controlled by the operator. These include SUN operation, STAR operation and OFF which are controlled by the power switch, and the standby or star OFF mode which is controlled by the STAR switch. Sun mode of operation arranges daylight sun tracking. Star mode of operation permits tracking of bodies of star intensity and can function with or without the aurora filter (see paragraph 2-11a.). Standby or star OFF mode holds the system out of the search and tracking modes while the operator applies initial input information.

2-8. FUNCTIONAL MODES. Functional modes include those modes of operation which are automatic. These include search, track, and north or south hemisphere operation. Search mode commences initially when standby mode is manually terminated by moving the STAR switch from the OFF position. This permits the

tracking telescope to scan a small area of the sky until a body is located at which time search terminates. If, for any reason the body is lost and tracking mode terminates, search will automatically resume. Tracking mode begins automatically when a body of sufficient light intensity falls within the tracker's field of view. Should the body be obscured during tracking, tracking mode terminates and the system reverts to search mode. North or south hemisphere operation is automatically controlled as the system passes from one hemisphere to the other. This provides a full sphere of operation on a necessarily hemispherical computations system.

2-9. PROTECTIVE MODES. Protective modes of operation include those modes which serve to prevent electrical or mechanical damage to the system due to improper operation or operation at limits in mechanical or electrical range. These include phototube protect, computer limit and power time delay modes. Phototube protect mode of operation will commence when the system, in star mode, is exposed to an excessive level of light. The system is automatically returned to the sun mode of operation when phototube protect is triggered. Phototube protect sustains until the operator manually switches the system to SUN operation. Phototube protect mode is indicated by the SUN lamp on the INDICATOR Display panel. Computer limit operations automatically commences when the mechanical limits of the analogue unit in the Altitude and Azimuth Computer are approached. Limit operation will drive the computer in a direction so as to move away from the limit. Limits exist in declination, latitude and altitude, and altitude limit operation is indicated by the ALT LIMIT lamp on the INDICATOR Display panel. A seven minute power delay mode is initiated upon the application of power to the system. This provides a warm up period so that when normal operation commences, all the systems functions will become operative simultaneously.

TABLE II

OPERATING CONTROLS

CONTROL	FUNCTION	LOCATION
Power-Filter Switch	1. Provides ON-OFF control for system power. 2. Selects sun (SUN) or star (STAR) mode of operation. 3. Selects AURORA FILTER in star mode of operation.	Master Control Panel
RATE Switch	Selects rate at which GHA input advances, SOL for solar rate and SID for sidereal rate.	Master Control Panel
SET Switch	1. Selects input function slewing for CLOCK, GHA, and Star Data. 2. "Hacks" CLOCK and GHA functions. 3. In the MANUAL SET position, it routes set selection to the MANUAL SET switch.	Master Control Panel
SET CONTROL	"Sprung to center off" potentiometer control which drives the input function selected by the SET switch or the MANUAL SET switch.	Master Control Panel
MANUAL SET Switch	Selects input slewing function for manually applied latitude and longitude when the SET switch is in the MANUAL SET position, and heading correction when the system is in standby mode and the SET switch is in the MANUAL SET position.	Manual Set Panel
LAT-LONG Switch	Permits the operator to select either externally generated present position information in the AUTO position, or internally generated present position displayed on the Manual Present Position Display panel in the MANUAL position.	Manual Set Panel
STAR Switch	1. Selects standby mode of operation in the OFF position. 2. Terminates standby and initiates search mode in the 1, 2, or 3 position. 3. Applies star information to the system from STAR DATA 1 panel in the OFF position, and star information from the STAR DATA panel of corresponding number in the 1, 2, or 3 position. 4. Precludes set function for the STAR DATA panel corresponding to positions 1, 2, or 3. All panels may be set with STAR switch in the OFF position.	Master Control Panel
PHOTOTUBE Switch	Selects for system operation one of two phototubes in the Astro Tracker. A standby phototube is provided to improve system reliability.	Master Control Panel

2-10. OPERATING CONTROLS. The following paragraphs describe the function and location of the systems operating controls. Table II is a listing of these controls with their function. All the operating controls are located on two panels. Six primary controls are located on the MASTER CONTROL panel and two secondary controls are located on the Manual Set panel.

2-11. MASTER CONTROL PANEL. (See figure 2-1.) The MASTER CONTROL panel provides six operating controls which are described in the following paragraphs in the general order of use.

a. Power Off-Filter Switch. This is a rotary, four position switch which applies power to the system and selects either sun mode of operation in the SUN position, or star mode of operation in the STAR or the AURORA FILTER position. The function of the AURORA FILTER position is to permit star tracking when the star image is obscured by auroral displays.

b. RATE Switch. The rate switch is a two position toggle which selects either solar (SOL) or sidereal (SID) rate of change for Greenwich hour angle, SOL for sun tracking and SID for star tracking (see Table 2-2 for planet rates).

c. SET CONTROL. This is a rotary potentiometer control through which the several input functions may be manually set on the appropriate counter indicators.

Figure 2-1. Operating Controls—Master Control Panel

The switch is sprung and detented to center which is the off position. Displacement of the control from its center position will cause the selected counter to slew slowly for small displacements and more rapidly for greater displacements. Clockwise displacement will cause increasing counter indications and counterclockwise displacement will cause decreasing indications.

Note

Latitude and declination are taken as increasing from south 90° through zero to north 90°.

d. SET Switch. This is a nine position rotary switch which selects the function to be set by the SET CONTROL. SET switch will select eight functions which are not ordinarily received automatically and therefore must be applied manually. These are CLOCK, GHA, SHA 1, DEC 1, SHA 2, DEC 2, SHA 3 and DEC 3. The ninth position, labeled MANUAL SET, transfers set function selection to the MANUAL SET switch on the Manual Set Panel. Movement of the SET switch into the CLOCK or GHA positions requires force greater than that required for switching into the other positions. This is to prevent interruption of time rate drive to these functions by accidentally overshooting the SHA 1 position.

Note

Star data information can not be set into the STAR DATA Display panel corresponding to the position in which the STAR switch is set. With the STAR switch in the OFF position, all three of the STAR DATA Display panels may be set.

e. STAR Switch. This is a four position rotary switch which selects the standby mode of operation in the OFF position, or the search or tracking mode of operation in the 1, 2, or 3 position. STAR switch positions 1, 2 or 3 will direct the tracker to look at the position in the sky described by STAR DATA Display panels 1, 2 or 3 respectively. Placing the STAR switch in position 1, 2 or 3 precludes the ability to set the functions of those respective panels. With the STAR switch in the OFF position, the computers and the tracker will be positioned in accordance with information displayed on STAR DATA 1 panel although the system will neither search nor track.

f. PHOTOTUBE Switch. This switch is a two position rotary switch which selects one of two phototubes for operation. Phototube number one, as selected by the number "1" position of the switch, is normally used for operation, while phototube number two, as selected by the number "2" position of the switch, will normally be used as a spare or emergency position only.

2-12. MANUAL SET PANEL (See figure 2-2). The Manual Set panel provides two operating controls required only for manual operation of the system. The controls are described in the following paragraphs.

a. LAT-LONG Switch. This is a two position rotary

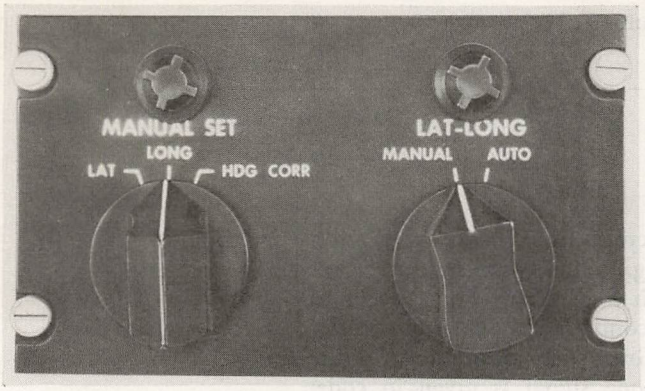

Figure 2-2. Operating Controls—Manual Set Panel

switch which selects the manual mode of operation (MANUAL) when the system requires internally generated latitude and longitude as displayed on the Manual Present Position Display Panel, or the automatic mode of operation (AUTO) when the system is receiving externally generated, automatic latitude and longitude.

Note

This switch will ordinarily be in the AUTO mode of operation and accepting externally generated latitude and longitude. The Manual Present Position Display panel does *not* repeat externally applied latitude and longitude. Do *not* accept information from this panel except when the LAT-LONG switch is in the MANUAL position.

b. MANUAL SET Switch. This is a three position rotary switch which selects manual slewing by the SET CONTROL for the three input functions ordinarily received from external equipment as automatic information. It is required that the SET switch on the MASTER CONTROL panel be in the MANUAL SET position before the MANUAL SET switch will function. The LAT and LONG positions of the MANUAL SET switch will select the LATITUDE and LONGITUDE functions of the Manual Present Position Display panel respectively for slewing. Manually set latitude and longitudes will be transmitted to the system only if the LAT-LONG switch is in the MANUAL position. The HDG. CORR (heading correction) position of the MANUAL SET switch provides set control of the HEADING CORRECTION function of the Heading Display panel. This function is controlled only when the system is in the standby, or search modes of operation. When the system is in the tracking mode, HEADING CORRECTION is being automatically computed and displayed, and setting manually is not possible.

2-13. OPERATING PROCEDURES.

2-14. PRIOR TO TAKE OFF.

2-15. Before starting the system, check to see that the operating controls are in the positions described below (see figure 2-1 and 2-2).

a. Power off switch to the OFF position.

b. SET switch to the CLOCK position.

c. STAR switch to the OFF position.

d. PHOTOTUBE switch to the 1 position.

e. RATE switch in either position.

f. MANUAL SET switch in the LAT position.

g. LAT-LONG switch in either position.

2-16. The following are step by step operating procedures (see figures 2-1 and 2-2).

a. Turn the power off switch to the SUN position. This applies power to the system. Wait two minutes before atempting to procede.

b. With the SET switch in the clock position, rotate the SET CONTROL clockwise or counterclockwise to set the clock (GMT) for the Greenwich mean time slightly in advance of present time.

Note

Placing the SET switch in the CLOCK position will stop the clock to permit accurate setting. Moving the set switch to any other position will start clock operation.

Referring to a reliable time tick (see Table IV), start the clock at the moment it reads the correct time by moving the SET switch from the CLOCK position to the GHA position.

TABLE III

PLANET RATES

Planet	Approximate Variation One Hour	Rate Switch Position
Venus	14°59.4′	SOL
Mars	15°00.8′	SOL
Jupiter	15°02.5′	SID
Saturn	15°02.5′	SID

c. Set the RATE switch to the SID or SOL position depending on the type of body to be tracked. Set to the SUN position for SUN tracking, or for tracking planets the GHA rate of which approximates sun rate (see table III). Set to the SID for star tracking, or planets the GHA rate of which more closely approximates Aries or sidereal rate.

d. With the SET switch in the GHA position, rotate the SET CONTROL clockwise or counterclockwise to read GHA of the sun for sun tracking, Aries for star

TABLE IV
TIME SIGNALS

WWVH Honolulu, T. H.

Time (GMT)	Frequencies (kc)	Remarks
Continuous	5000, 10000, 15000, 20000, 25000	Western Pacific, Eastern Asia

Note

This transmission is in five minute cycles throughout every hour. A continuous tone is transmitted beginning on the first and ending after the fourth minute of each five minute cycle. Ticks at one second intervals are presented continuously. During the last minute of each five minute cycle, Greenwich mean time for the commencement of the succeeding tone signal is given in code. The entire broadcast is interrupted for four minutes following each hour and half hour.

NSS Washington, D. C.

Time (GMT)	Frequencies (kc)	Remarks
0155	122, 4390, 9425, 12630	
0255	4390, 9425, 12630	
0355	122, 4390, 9425, 12630	
0455	9425	
0555	122, 4390, 9425, 12630	
0655	9425	
0755	122, 4390, 9425, 12630	
0855	4390, 9425, 12630	
0955	122, 4390, 9425, 12630	
1155	122, 4390, 9425, 12630	
1255	9425	
1355	122, 4390, 9425, 12630	
1455	9425, 12630, 17370	
1555	122, 4390, 9425, 12630	
1655	9425	
1755	122, 4390, 9425, 12630	
1855	9425	
1955	122, 4390, 9425, 12630, 17370	
2055	9425, 12630, 17370	
2155	122, 4390, 9425, 12630, 17370	
2255	9425	
2355	122, 4390, 9425, 12630	

Note

The signals begin at five minutes before the hour and consist of a dash on each second except that no dashes are sent on the seconds listed following.

55 minutes — 29, 51 and 56 to 59
56 minutes — 29, 52 and 56 to 59
57 minutes — 29, 53 and 56 to 59
58 minutes — 29, 54 and 56 to 59
59 minutes — 29, and 51 to 59

Beginning exactly on the hour a much longer dash is sent. The exact second is denoted by the beginning of the dash and the end of the dash bearing no significance.

TIME SIGNALS (Cont)

WWV Washington, D. C.

Time (GMT)	Frequencies (kc)	Remarks
Continuous	2500, 5000, 10000, 15000, 20000, 25000, 30000, 35000	U. S., South America, Atlantic Canada, Eastern Pacific, Mexico

Note

This transmission is in five minute cycles throughout every hour. A continuous tone is transmitted beginning on the first and ending on the fourth minute of each five minute cycle. Ticks at one second intervals are presented continuously. During the last minute of each five minute cycle, GMT for the commencement of the succeeding tone signal is given in code, and Eastern Standard Time is given by voice.

BBC Overseas Service

Time (GMT)	Frequencies (kc)	Remarks
0000	9600, 12040	Atlantic, Africa, Europe and E. Asia
0200	6035, 6050, 7135, 7185, 9410, 9510	Atlantic, Africa, Europe and E. Asia
	6110, 9560, 9825	N. Atlantic
0500	7230, 9410, 11930, 12095	Atlantic, Africa, Europe and E. Asia
	7185, 9600, 9770, 11750, 11770	Africa
0600	7150, 7230, 9410, 9510, 9640, 11930, 12095	Atlantic, Africa, Europe and E. Asia
	7185, 9600, 9770 11750, 11770, 15110	Africa
	6110	N. Atlantic
0700	7150, 7185, 9410, 9510, 9640, 11910, 11995, 12095	Atlantic, Africa, Europe and E. Asia
	9770, 11750, 11770, 15110	Africa
0800	9735, 9760, 11910, 11955	Atlantic, Africa, Europe, Asia
0900-0955	15360, 15375, 17890	Atlantic, Africa Europe and Asia (Weekdays only) (every 5 minutes)
1100	11750, 11930, 15070, 15260, 15360, 15375, 15400, 17715, 17740, 17840, 17890, 21470, 21630	Atlantic, Africa, Europe, Asia
	15110, 17870	Africa

TIME SIGNALS (Cont)

BBC Overseas Service (cont'd)

Time (GMT)	Frequencies (kc)	Remarks
1200	12095, 15375, 17890	Atlantic, Africa, Europe, Asia
1300	7230, 9410, 9760, 11680, 11750, 11930, 15070, 15375, 15400, 17715, 17810, 7890	Atlantic, Africa, Europe, Asia
	5110, 17870, 21470	Africa
1400	7230, 9410, 11750, 15070, 15260, 15400, 17715, 17740, 17810	Atlantic, Africa, Europe, Asia
	15110, 17870, 21470	Africa
1500	1536	Atlantic
1600	11750, 12095, 15070, 15180, 15400, 17715, 17810	Atlantic, Africa, Europe, Asia (Except Saturday)
	15110, 17870, 21470	Africa (Except Saturday)
	15360	Atlantic
1700	15360	Atlantic
1800	6035, 7230, 9410, 9510, 11750, 11800, 12095, 15070	Atlantic, Africa, Europe, Asia
	9600, 11820, 11955, 15110	Africa
	15360	Atlantic (Mon., Wed., Thurs., Fri.)
2000	7320, 9410, 11750, 11800, 11910, 12095, 15180, 15260	Atlantic, Africa, Europe, Asia
	7185, 9510, 9600, 11820, 11955, 15110	Africa
	11930	Atlantic (Weekdays)
2100	9825, 11800, 2095, 15180, 15260	Atlantic, Africa, Europe, Asia
	7185, 9510, 9600, 11820, 11955	Africa
	11930	Atlantic
2300	6035, 7185, 9410, 9510, 11800, 12095	Atlantic, Africa, Europe, Asia
	6110, 9560, 9825	Atlantic

Note

BBC ticks are a series of six dots starting on the last 55th second of each hour. The beginning of the sixth dot is the start of the next hour.

tracking, or the appropriate planet for planet tracking on the GHA counter located on the Indicator Display Panel. Set GHA slightly in advance of present GHA.

Note

Placing the SET switch in the GHA position will stop the GHA drive to permit accurate setting. Moving the SET switch to any other position will start GHA operation at a rate corresponding to the position of the RATE switch. GHA may be determined from the air almanac.

Referring to the GMT clock, start GHA at the time for which it reads correctly by moving the SET switch to the SHA 1 position. GHA will begin to drive at the rate specified by the position of the RATE switch.

e. With the SET switch in the SHA 1 position rotate the SET CONTROL from its center position to drive SHA in STAR DATA 1 panel. Set SHA to the proper value for the star to be tracked as determined from the Air Almanac.

Note

For sun or planet tracking, SHA counter must be set to zero.

Note

When selecting a star for tracking, it is best, though not necessary, to choose a low, rising star or a high, setting star to provide maximum continuous tracking time. It is also advisable to choose a star that will be forward of the aircraft since small errors in azimuth computation caused by small errors in automatic present position will cause convergent errors in true heading with relative bearing between 270 degrees and 90 degrees. Tracking stars aft of the aircraft will cause divergent errors in true heading. Star tracking should be limited to stars between six and sixty degrees in altitude for best results.

f. Move the SET switch to the DEC 1 position. Offset the SET CONTROL to drive the declination (DEC) counter on STAR DATA 1 panel to read proper declination as determined from the Air Almanac for the same body for which SHA 1 was set.

g. Move the SET switch to the SHA 2 position. Offset the SET CONTROL to drive SHA counter on STAR DATA 2 panel. Set SHA 2 to the value as determined from the Air Almanac for a second body (See note in paragraph 2-16e).

Note

Tracking requires that only one Star Data Display panel be set. Additional panels may be set with star information for standby or for three star fix procedure. Additional panels may be set before or during tracking.

h. Move SET switch to DEC 2 position. With the SET CONTROL switch, set DEC counter on STAR DATA 2 panel to the declination for the same body represented by the STAR DATA 2, SHA counter.

i. Move SET switch to SHA 3 position and with the SET CONTROL switch, drive the SHA counter on STAR DATA 3 panel. Set SHA 3 for a third body as determined by the Air Almanac (see note on paragraph 2-16e).

j. Move SET switch to DEC 3 position, and with the SET CONTROL switch, drive the DEC counter on STAR DATA 3 panel. Set DEC 3 for the same body as represented by the STAR DATA 3, SHA counter.

k. Move SET switch to MANUAL SET position. With the MANUAL SET switch on the Manual Set panel in the LAT position, drive the LATITUDE counter on the Manual Present Position Display panel by rotating the SET CONTROL switch clockwise or counterclockwise. Set appropriate latitude on this counter to correspond to expected position when tracking will commence.

Note

During ordinary operation, present position information will be accepted as continuously computed externally applied signals. In this case it will be unnecessary to apply latitude and longitude manually. During automatic operation, information presented by the Manual Present Position Display panel is irrelevant and must not be considered. During manual operation, manually set present position as presented by the Manual Present Position Display panel is applied to the system and may be taken as assumed present position for altitude intercept readings. True heading developed on the basis of manually set present position will be accurate when present position presented by the Manual Present Position Display panel is accurate, but true heading may be in error when this presentation is not accurate. During manual operation, LATITUDE and LONGITUDE counters should be reset frequently to maintain accurate true heading computation.

l. Move MANUAL SET switch to the LONG position. Drive the LONGITUDE counter on the Manual Present Position Display panel by rotating the SET CONTROL clockwise or counterclockwise. Set appropriate longitude on this counter to correspond to expected position when tracking will commence.

m. Move MANUAL SET switch to the HDG CORR. (heading correction) position. Drive HEADING CORRECTION counter on the Heading Display panel to set appropriate heading correction. Heading correction is the difference between externally applied best available true heading and actual true heading. Ordinarily, applied best available true heading will be a close approximation of actual true heading in which case HEADING

CORRECTION counter must be set to zero. However, where error in best available true heading is known, negative heading correction should be applied for positive errors and positive correction for negative errors. It is necessary that best available true heading plus heading correction be within four degrees of actual true heading. Before tracking begins the TRUE HEADING counter reads best available true heading plus heading correction.

2-17. IN-FLIGHT PROCEDURES.

2-18. The following procedures will ordinarily be performed after the aircraft is airborne. However, these procedures are applicable at any time when tracking is required. In general, the system should not be used during take-off period since turning maneuvers in excess of 23 degrees per minute, roll maneuvers in excess of 15°, and pitch maneuvers in excess of 15° cause the system to stop tracking. Even though not tracking, the system should be energized and in the standby mode during take-off.

a. After the aircraft is in straight and level flight, and if operating in the MANUAL position of the LAT-LONG switch, when the aircraft is over the point described by the information displayed by the Manual Present Position Display panel, turn the STAR switch to the number "1" position to track the body located by information displayed on STAR DATA 1 panel. If this is a night time body (star or planet) place the power off switch in the STAR position. The system will begin search and lock on the selected body.

Note

It takes approximately fifty seconds to complete one search cycle. Allow the system two cycles to locate the star before initiating check-out procedures described in paragraph 2-27.

When the system has located a celestial body and commenced tracking, tracking mode will be indicated by illumination of a TRACK lamp on the INDICATOR Display panel. Track lamps are labeled 1, 2 and 3 to correspond to STAR DATA panels 1, 2 and 3. Allow approximately one minute for the search pattern to completely collapse before system outputs are taken to be accurate.

b. If the LAT-LONG switch is in the AUTO position and automatic latitude and longitude are being applied to the system from an external source, tracking may be initiated when the aircraft is straight and level and external latitude and longitude information is accurate.

2-19. DURING USE.

2-20. The following procedures should be observed during the progress of a flight.

a. Periodically during a flight the GMT clock and the GHA counters should be checked for accuracy. See paragraph 2-25 for evaluation of abnormal indications.

b. The ALT dial on the INDICATOR Display panel should be checked periodically to be sure that the body is within suggested good tracking range as described by the area outside the cross-hatching on the dial (between 6 degrees and 60 degrees). When the body approaches one of these limits, where possible a different, more suitable body should be used.

c. Maintain a periodic check of all indicators for abnormal readings as described in paragraph 2-25.

d. When operating in the manual mode (LAT-LONG switch in the MANUAL position) periodically, or whenever accurate readings are required, determine accurate latitude and longitude and reset counters on the Manual Present Position Display panel as per paragraph 2-15, k and l.

e. When the system has been tracking the sun, and the sun has gone below the horizon, there will be a period of twilight during which neither sun nor star tracking will be possible. During this period the system should be put in the standby mode by placing the STAR switch in the OFF position to suspend search operation. The operator may then prepare for star operation by following set up procedure. Note in particular that GHA must be reset and the RATE switch properly positioned.

f. During the morning twilight period when star tracking is no longer possible, the system should be put in the standby mode by placing the STAR switch in the OFF position. The power off switch must be placed in the SUN position to prevent possible damage to the phototube due to exposure to the increasing sky light. The system may then be prepared for sun tracking. Note in particular that GHA must be reset and the RATE switch placed in the SOL position.

g. For consecutive star operation when only true heading computation is required, three different stars set on the three STAR DATA panels may be selected so that as one star approaches undesirable tracking altitude as described by the cross hatched area on the ALT dial, a second, more suitable star is ready for tracking on a second STAR DATA panel. Place the STAR switch in the position corresponding to the STAR DATA panel which describes the position of the more suitable star. The system will then search for and track the second star.

h. For three star fix operation, three stars, approximately 120 degrees displaced in azimuth and approximately 45 degrees in altitude should be set on the three STAR DATA panels. Set STAR switch in the 1 position. After tracking has commenced as indicated by illumination of TRACK lamp number 1, wait until the ALTITUDE INTERCEPT counter on the Line of Position Display panel has stopped driving and note readings on TRUE AZIMUTH and ALTITUDE INTERCEPT counters.

Note

ALTITUDE INTERCEPT counter may oscillate several nautical miles over a period of 1.5 to 2 minutes. Take an average of the extreme readings. Apply correction for refraction.

Take assumed present position from Manual Present Position Display panel if operating in the manual mode, and, if in the automatic mode, take present position from the latitude and longitude display provided by the external equipment supplying this information to the MD-1. Plot LOP in the usual manner. Do not apply correction to LOP since read-outs are instantaneous computations and the system is automatically corrected for horizontal bubble errors. Track star number two by placing the STAR switch in the number "2" position and proceed as above. Repeat procedure for star number three by placing the STAR switch in the number "3" position.

Note

In the manual mode where latitude and longitude are provided by the Manual Present Position Display panel, assumed present position remains constant and need be noted only once. However, in automatic operation, latitude and longitude are continuously changing and must be noted separately for each star.

2-21. SECURE.

2-22. Securing operations should follow touchdown of aircraft at end of flight. Return LAT-LONG switch, MANUAL SET switch, STAR switch, PHOTOTUBE switch and SET switch to extreme counterclockwise position. Turn the Power off switch to the OFF position.

2-23. NORMAL INDICATOR PRESENTATIONS.

2-24. The following paragraphs describe the system displays along with their normal indications.

a. TRUE HEADING Counter. Before the system starts tracking, this counter reads the algebraic sun of externally applied best available true heading and manually applied heading correction. When the system is tracking a celestial body this counter reads accurate true heading.

b. HEADING CORRECTION counter. Before the system is tracking this counter reads manually applied heading correction or last computed value for heading correction. When the system is tracking, HEADING CORRECTION counter reads measured difference between actual true heading and best available true heading. During tracking this counter and the TRUE HEADING counter will oscillate over a small range of one or two minutes of arc.

c. TRUE AZIMUTH Counter. This counter reads star azimuth computed by the Altitude and Azimuth Computer based on applied latitude, longitude, SHA, declination and GHA. Errors in applied present position will cause errors in true azimuth reading, but since these errors are small, they are taken to be negligible. During search mode of operation the TRUE AZIMUTH counter will oscillate with relative bearing search indicating that a search pattern is being developed.

d. ALTITUDE INTERCEPT Counter. Before the system starts tracking, this counter will read a steady zero. The counter is automatically returned to zero whenever the system is not tracking. When the system is in the tracking mode the ALTITUDE INTERCEPT counter reads the difference between computed altitude based on applied inputs to the Altitude and Azimuth Computer, and actual altitude measured by the tracker. Where applied present position information is accurate, ALTITUDE INTERCEPT counter should oscillate around or near zero during tracking.

e. ALT Dial. This dial gives an approximate value for celestial altitude as computed by the Altitude and Azimuth computer. Its function is to inform the operator when the star is within good tracking range. Normally the indication should read between six degrees and sixty degrees in altitude.

f. GHA Counter. This counter reads present GHA of the sun, planets, or aries as selected by the operator. After an initial value for GHA is applied by the operator, the counter is automatically driven at a rate to maintain continuous, present information. The GHA counter will remain stationary only when the SET switch is in the GHA position.

g. GMT Clock. The GMT clock displays continuous Greenwich mean time after the operator has manually set initial information. The clock will be stationary only when the SET switch is in the CLOCK position.

h. TRACK lamps. The TRACK lamps, numbered 1, 2 and 3 will be extinguished when the system is not tracking. When the system recognizes the presence of a star, the TRACK lamp numbered in accordance with the position of the STAR switch will illuminate indicating tracking mode of operation.

i. SUN Lamp. The SUN lamp will normally be extinguished and will illuminate only when the phototube is exposed to an excessive value of light which causes the system to initiate sun protect mode of operation. Illumination of the SUN lamp requires action by the operator to determine and eliminate the cause of excessive exposure.

j. ALT LIMIT Lamp. This lamp will illuminate only when information applied to the Altitude and Azimuth computer causes the computer to drive to an electrical altitude limit. To prevent mechanical damage, the system will automatically initiate altitude limit operation. This condition is indicated by the flashing ALT LIMIT lamp. The operator may determine high or low limit by referring to the ALT dial. Although it is suggested that the operator avoid driving the system to its limits, in some cases during set up operation approaching the limits is unavoidable. The operator may proceed to apply proper input information and the computer will automatically bypass altitude limits and position itself in conformance with final inputs.

k. STAR DATA, LATITUDE and LONGITUDE. These counters are manually positioned by the operator

and display fixed information. LATITUDE and LONGITUDE counters do not follow automatically applied present position information.

2-25. ABNORMAL INDICATOR PRESENTATIONS.

2-26. The following paragraphs describe indicator presentations indicating a malfunction or improper operation.

a. Fuses. (See figure 2-3.) There are eight indicator fuses located on the front of the Power Supply package. If the lamp in the fuse cap is illuminated it is an indication that the fuse is out. Replace with an appropriate spare fuse located at the bottom of the Power Supply front plate.

b. HEADING CORRECTION Counter. In most installations of the MD-1, best available true heading will be a good approximation of actual true heading and heading correction will be a small value. Where the HEADING CORRECTION counter reads a large value (approximately a degree or more) it is suggested that input information be checked for accuracy and that an alternate star be tracked to eliminate the possibility of ambiguous tracking (see table V for possible ambiguities). If input information is accurate and HEADING CORRECTION counter is consistent over two or more stars, this information may be taken as accurate.

c. ALTITUDE INTERCEPT Counter. During tracking, ALTITUDE INTERCEPT counter should read close to zero. Large values of altitude intercept indicate error in applied information or ambiguous tracking. Check accuracy of input information or track a second star approximately 180 degrees displaced in azimuth. If the second star produces an intercept of approximately the same value but opposite in sign, latitude or longitude may be in error. If in addition it can be determined that input information is accurate, consult Section III for inflight test procedures.

d. TRUE AZIMUTH Counter and ALT Dial. If either the TRUE AZIMUTH counter or the ALT dial oscillate rapidly around a particular value, it may imply operation of the Altitude and Azimuth Computer in a limit other than the altitude limits. Latitude limits exist at approximately plus ninety degrees and minus two degrees. Declination limits exist at plus (same name as latitude) ninety degrees approximately, and minus (name opposite to latitude) 47 degrees. In neither case will there be direct indication of limit operation except in the rapid oscillation of the TRUE AZIMUTH counter or the ALT dial.

e. SUN Lamp. When the SUN lamp illuminates, it is an indication that the phototube has been exposed to an excessive level of light. Determine and if possible, eliminate the cause or source of excessive light. The system may be returned to normal operation by moving the Power switch to the SUN position and then back to the STAR or AURORA FILTER position.

f. ALT LIMIT Lamp. A flashing ALT LIMIT lamp indicates that the Altitude and Azimuth Computer is operating in a high or low altitude limit. This may occur during set up operation and when proper input information is completely set into the system, the computer will automatically come out of its limit. If limit operation persists for more than approximately sixty seconds, check for correct inputs (correct hemisphere flags on counters, etc). When the STAR switch is in the OFF position, star data is applied to the Altitude and Azimuth Computer from the STAR DATA 1 panel. Therefore, the star selected for display on STAR DATA 1 panel should be within the altitude range of the computer (minus six degrees to 85 degrees approximately). When the ALT LIMIT lamp lights during tracking operation, select a different star.

g. TRACK Lamps. If, during tracking, the TRACK lamp extinguishes or if the system fails to track initially, check sky conditions for star visibility. Auroral displays may interfere with tracking of stars in the area of the display. Move the Power switch to the AURORA FILTER position to improve tracking ability under this condition. (See paragraph 2-27 for procedures when system fails to track.)

2-27. FAILURE TO TRACK.

2-28. The following procedures are suggested when the system fails to track a selected body after about three minutes of switching to STAR switch position 1, 2 or 3.

a. Check sky condition and position of selected body to determine visibility. Partial obscuration reduces apparent magnitude. (See paragraphs 2-2, 2-3 and 2-4.)

b. Check fuses on front plate of power supply. A burnt fuse will be indicated by illumination of the fuse cap.

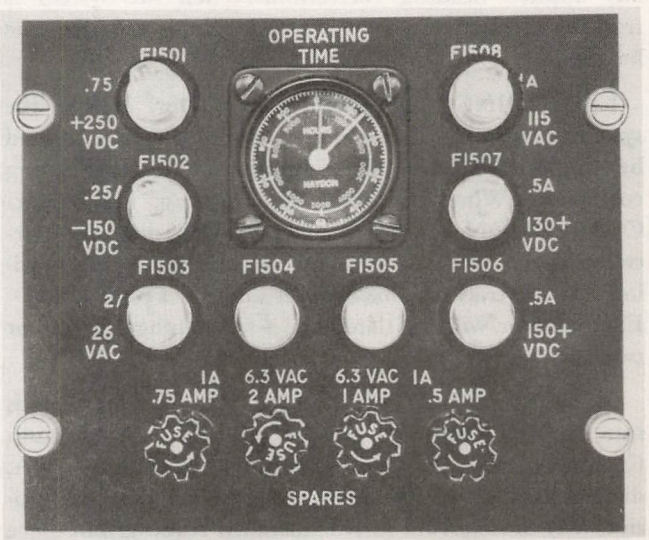

Figure 2-3. System Fuses

c. Check all inputs for accuracy. Check counter flag designation (N, E, S, W). Check for accurate Greenwich Time.

d. Check clock for proper rate by timing against stop watch for one minute. If the clock is driving incorrectly there will be approximately six seconds error per minute.

e. Switch to phototube number two by turning PHOTOTUBE switch to number "2" position to determine operability of the tube.

f. Check operation of search pattern by noting slow oscillation of TRUE AZIMUTH counter.

g. Check TRUE HEADING counter against second source. Before Tracking, the TRUE HEADING counter must be accurate to plus or minus four degrees. Correct to approximate true heading by slewing HEADING CORRECTION counter.

h. Check proper position of switches. Check Power switch in SUN position for sun operation and STAR or AURORA position for star operation. Check SET switch to be sure that it is not in the GHA or CLOCK position. Check STAR switch to see that it is positioned to correspond to the STAR DATA package number displaying the selected body. Check RATE switch for appropriate positioning.

i. Select to track a second star in a different area of the sky.

2-29. OPERATING PRECAUTIONS.

2-30. The following precautions should be noted by the operator to prevent possible damage to the equipment and faulty operation due to improper procedures.

a. Altitude Limits. The system is restricted in celestial altitude to the area between approximately minus six degrees and plus eighty-five degrees. Although the system is provided with automatic electrical limiting devices to prevent damage due to operation outside these limits, prolonged operation at the limits is dangerous to the system. The ALT LIMIT lamp will illuminate to indicate altitude limit operation.

b. Sun Warning. If the Power switch is in the STAR position during daylight hours, or a bright light appears at night, the SUN warning lamp will light to indicate that the light received by the phototube is excessive and the Power switch may be in the wrong position.

c. Latitude and Longitude Inputs. The accuracy of system outputs deteriorates as latitude and longitude information becomes inaccurate. Therefore, latitude and longitude inputs must be changed whenever it is determined that they are in error.

d. Latitude Limits. Latitude is electrically limited to a range between minus two degrees and plus ninety degrees approximately. A hemisphere switching mechanism extends the latitude range over 180 degrees.

Note

"Plus" indicates latitude in the hemisphere of operation. "Minus" indicates opposite hemisphere.

Although the system is electrically protected against damage in limit operation, extended operation in the limits is not advised. There is no indication of latitude limit operation with the possible exception of a slight oscillation of the TRUE AZIMUTH counter or the ALT dial. However, since the system's range in latitude includes all latitudes, limits will not be encountered in normal operation.

e. Hemisphere Switching. When the latitude input to the system drives latitude gear train from one hemisphere to the other, a switching operation is initiated to reverse the computers for opposite hemishpere operation. If the latitude inputs to the system are not operative (i.e. if the external source of present position is turned off) the latitude gear train may have a tendency to drift from one hemisphere to the other. This action will trigger hemisphere switching but the uncontrolled gear train will continue to drift to its minus two degree limit leaving the hemisphere switching cycle incomplete. When latitude control is reestablished, the half completed hemisphere switching will cause continuous oscillation in and out of the minus two degree latitude limit. Under these circumstances, normal operation may be restored by manually driving latitude to the opposite hemisphere thus completing hemisphere switching. Latitude may then be driven back to its original setting. It is suggested that the system be put in the manual mode of operation when external present position is inoperative.

f. Declination Limit. Declination limits exist at plus ninety degrees (same as latitude) and minus forty-seven degrees (opposite to name of latitude). Electrical limit operation will protect the system from damage, but extended operation in the limits is not advised. There is no specific indication of declination limit operation except as implied by rapid oscillation of either the TRUE AZIMUTH counter or the ALT dial. When attempting to track stars in the hemisphere opposite to latitude, particular note should be made of the minus forty-seven degree limit.

g. Hemisphere Switching and Declination Limit. When hemisphere switching is activated, values of declination that were formerly plus become minus declinations. Stars that were trackable at declinations above forty seven degrees plus or same name as latitude will drive to the low declination limit when the name of latitude changes. The operator should choose stars below forty seven degrees in declination when operating near the equator.

h. Ambiguous Stars. In a limited number of instances there are stars of trackable magnitude in close enough proximity to one another to be included in a single search area. It is possible in this circumstance that the tracker will sight and track an incorrect star and develop erroneous computations. This may be noted by otherwise unexplainable large values of HEADING CORRECTION or ALTITUDE INTERCEPT. In order that the

operator may avoid these ambiguities, Table V lists the described instances.

i. Switch Positions. When the system is running but not in use the Power switch should be in the SUN position to prevent exposure of the phototube to excessive light, the STAR switch should be in the OFF position to place the system in the standby mode, and the LAT-LONG switch should be in the MANUAL position to prevent driving the system into one of its limits when not attended.

TABLE V

POSSIBLE STAR AMBIGUITIES

STAR	PHOTOELECTRIC MAGNITUDE	NEAR NEIGHBOR	PHOTOELECTRIC MAGNITUDE	SEPARATION IN SHA DEG.	SEPARATION IN SHA MIN.	SEPARATION IN DECLINATION DEG.	SEPARATION IN DECLINATION MIN.
Arcturus	0.89	Bootis η	2.34	5	16	0	47
Rigel	0.30	Eridani β	2.97	1	42	3	06
Altair	1.00	Aquilae γ	3.54	1	07	1	45
Acrux	0.86	Crucis β	1.31	5	15	3	25
		Gacrux	2.54	1	08	6	00
Antares	2.09	Scorpii π	2.83	7	39	0	22
		Scorpii τ	2.67	1	46	1	47
Deneb	1.37	Cygni γ	2.70	4	49	5	00
Pollux	1.86	Castor	1.58	2	42	3	52
Nunki	1.99	Sagittarii λ	3.59	6	49	0	54
		Sagittarii ζ	2.76	1	49	3	36
Shaula	1.54	Scorpii υ	2.65	0	43	0	11
		Scorpii κ	2.34	2	13	1	56
Crucis β	1.31	Acrux	0.86	5	15	3	25
		Gacrux	2.54	4	06	2	35
Adhara	1.44	Canis Majoris η	2.32	6	22	0	18
		Canis Majoris δ	2.37	2	26	2	35
Alnilam	1.52	Orionis δ	2.25	1	03	0	54
		Orionis ι	2.44	0	11	4	42
		Orionis ζ	1.82	1	08	0	43
Orionis κ	1.97	Orionis ι	2.44	3	06	3	45
Carinae ι	2.47	Velorum κ	2.48	1	12	4	17
		Velorum N	3.79	3	29	2	15
Canis Majoris η	2.32	Canis Majoris δ	2.37	3	57	2	54
		Canis Majoris o^2	3.01	5	18	5	27
		Adhara	1.44	6	22	0	18
Scorpii δ	2.31	Scorpii π	2.83	0	24	3	28
		Scorpii β	2.70	1	17	2	50
Cassiopise γ	1.72 ave.	Schedar	3.00	4	00	4	11
Procyon	0.81	Canis Minoris β	3.05	3	04	3	02
Achernar	0.49	Hydri α	3.24	5	20	4	19
Mirfak	2.23	Persei γ	3.41	4	54	3	36
		Persei δ	2.99	4	39	2	03
Scorpii θ	2.26	Scorpii κ	2.34	1	20	3	58

SECTION III.
OPERATING CHECKS AND ADJUSTMENTS

3-1. INTRODUCTION.

3-2. This section describes preflight and inflight checks to determine operability of the system and its various functions. Since a suitable body for tracking is not always available during the period when the check is conducted, tests will be described both with and without a celestial body. However, checks conducted with a celestial body are more informative and are suggested where possible.

3-3. PREFLIGHT CHECKS WITHOUT CELESTIAL BODY.

3-4. The following checks are designed to test system function other than tracking ability before take off when no celestial body is visible or tracking is prevented by any cause.

3-5. Starting Time Delay Check.

a. Turn the Set Switch to SHA 1.

b. Turn the Star Switch to OFF.

c. Turn the Power Switch to SUN.

d. After 2 minutes, displace the Set Control knob to either extreme and hold.

e. Within 15 seconds the SHA counter in Star Data Display Panel No. 1 should rotate.

f. Release Set Control Knob. It should reutrn to neutral position and counter rotation should stop.

3-6. CLOCK RATE CHECK. GMT clock should operate except when SET switch is in the CLOCK position. Check clock rate against stop watch for one minute. If the clock is functioning incorrectly there will be an error of approximately six seconds at the end of one minute.

3-7. COUNTER AND DIAL ROTATION.

a. Set power switch to SUN position.

b. Set STAR switch to OFF position.

c. Set LAT-LONG switch to MANUAL position.

d. Set LATITUDE counter to 85 degrees N.

e. Set DECLINATION on STAR DATA 1 panel to 45 degrees N.

f. Set system controls in the sequence of Table VI. For each set of conditions column 3 indicates the direction of rotation of counter or dial affected for a CW rotation of the set control knob. CCW rotation of the set control knob should produce rotations opposite to that indicated. Operate set control knob as necessary to cause rotation of each counter and dial over the full range indicated in column 4. All counters and the clock dial should be run slowly at random points to locate high spots. When the STAR Switch (Master Control Panel) is at a numbered position (1, 2 or 3), it shall not be possible to set star information into the star data display panel of the corresponding number.

g. Set GHA to 15 degrees.

h. Set SHA 1 to zero.

i. Set DEC 1 to zero.

j. Set LONGITUDE to zero.

TABLE VI
COUNTER FUNCTION CHECKS

No.	MASTER CONTROL PANEL SET SWITCH	MANUAL SET PANEL MANUAL SET	ROTATION
1	Clock	—	TIME increase 24 hours
2	GHA	—	GHA increase 360°
3	SHA No. 1	—	SHA 1 increase 360°
4	SHA No. 2	—	SHA 2 increase 360°
5	DEC No. 2	—	DEC 2 increase N 90°S — 90°N
6	SHA No. 3	—	SHA 3 increase 360°
7	DEC No. 3	—	DEC 3 increase N 90°S — 90°N
8	MAN. SET	LONG	LONG increase E 180°E — 180°W
9	MAN. SET	HDG. Corr.	HDG. Corr. inc + +180° to —180° True Heading inc. 0° — 360°

k. Drive LATITUDE from 90 degrees N to 90 degrees S by rotating SET CONTROL counterclockwise.

l. Set LATITUDE to zero. Approach zero from southern hemisphere.

m. Drive DEC 1 to 90 degrees S by rotating SET CONTROL counterclockwise.

n. Set DEC 1 to zero.

o. Drive LATITUDE to five degrees N.

p. Drive Dec 1 to 90°N by rotating SET CONTROL clockwise.

3-8. COMPUTER LIMITS. The Altitude and Azimuth Computer will be driven to its several limits by introducing appropriate information. In each case satisfactory limit operation may be ascertained by observation of the ALT dial, ALT LIMIT lamp and the TRUE AZIMUTH counter.

3-9. LATITUDE HIGH LIMIT.

a. Set SHA No. 1 counter to zero.

b. Set LONGITUDE counter to zero.

c. Set GHA counter to zero.

d. Set DEC 1 to 20 degrees N.

e. Set LATITUDE counter to 92°N.

f. Observe ALT dial. Oscillation of the ALT dial will indicate that the limit has been reached.

3-10. LATITUDE ZERO LIMIT (HEMISPHERE SWITCHING).

a. Set LATITUDE to 03 degrees 00 minutes N.

b. Set LONGITUDE and SHA 1 to zero.

c. Set GHA to 60 degrees.

d. Set DEC to 30 degrees N.

e. Note value of TRUE AZIMUTH counter.

f. Move LATITUDE to 03 degrees 00 minutes S observing TRUE AZIMUTH repeater counter. TRUE AZIMUTH will swing approximately 90 degrees and then reutrn to within 10 degrees of reading observed in e.

3-11. DECLINATION 90 DEGREE LIMIT.

a. Set LONGITUDE and SHA to zero.

b. Set GHA to 90 degrees.

c. Set LATITUDE to 45 degrees N.

d. Set DEC to 92 degrees N.

e. Observe that TRUE AZIMUTH repeater counter oscillates.

3-12. DECLINATION 47 DEGREE LIMIT.

a. Set DEC to 50 degrees S.

b. Set LATITUDE to 05 degrees N.

c. Set LONGITUDE and SHA to zero.

d. Set GHA to 60 degrees.

e. Observe that the TRUE AZIMUTH repeater counter oscillates.

3-13. ALT 85 DEGREE LIMIT.

a. Set LONGITUDE and SHA to zero.

b. Set LATITUDE to 30 degrees N.

c. Set DEC to 30°N.

d. Set GHA to 30 degrees. Slew GHA to 330 degrees through zero by rotating Set Control CCW.

e. Blinking of the ALT LIMIT light and oscillation of the TRUE AZIMUTH counter will be observed. The oscillation and blinking will cease in 60 seconds or less after 330 degrees GHA are reached.

3-14. ALT ZERO DEGREE LIMIT.

a. Set LONGITUDE and SHA to zero.

b. Set LATITUDE to 30 degrees N.

c. Set DEC to 30 degrees S.

d. Set GHA to 30 degrees. Slew GHA to 330 degrees through 180 degrees by operating the SET CONTROL CW.

e. Blinking of the ALT LIMIT light and oscillation of the TRUE AZIMUTH counter will be observed. The oscillation and blinking should cease in 15 seconds or less after 330 degrees GHA are reached.

3-15. EXTERNAL INPUTS.

3-16. LATITUDE AND LONGITUDE.

a. Turn on the external equipment which provides the automatic inputs of Latitude and Longitude to the Astro Compass.

b. Place the LAT-LONG switch of the Manual Set Panel to the AUTO position.

c. Place the STAR Switch on the Master Control Panel to the OFF position.

d. Insure that all necessary airplane switches and/or those of the external LAT and LONG supply equipment are in the proper position for transmitting LAT and LONG to the Astro Compass.

e. Observe the Altitude dial on the indicator Display Panel. If the computer altitude is not within the range 15-65 degrees vary either SHA or Declination of Star Data Panel No. 1 until the altitude dial reads within this range.

f. Set the values of LAT and LONG on the Manual Present Position Display Panel to the same values as those of the external equipment.

g. Switch AUTO and MANUAL position on the Manual Set Panel and observe that the Altitude does not change and that TRUE AZIMUTH does not vary more than 2 minutes.

3-17. BEST AVAILABLE TRUE HEADING (BATH).

a. Place all airplane and/or external BATH supplying equipment switches in the proper position for supplying a BATH input to the Astro Compass.

b. Set the value of HEADING CORRECTION on the Heading Display Panel to zero.

c. Observe that the TRUE HEADING counter on the Heading Display Panel repeats the value of BATH supplied by the external equipment to within one degree.

d. Vary the BATH input and observe that the TRUE

HEADING continues to repeat the BATH input to within one degree.

3-18. COMPUTER ACCURACY.

3-19. The tests described in Table VII are designed to determine operability of the Altitude and Azimuth Computer. Before reading azimuth, check and reset GHA counter.

a. Set STAR switch to the OFF position.

b. Set LAT-LONG switch to the MANUAL position.

c. Set Power switch to the SUN position.

d. Set up each test in order and note TRUE AZIMUTH counter. Compare with calculated values in Table VII. Values shall not differ by more than twelve minutes.

3-20. PREFLIGHT TESTS WITH STAR. Whenever a Pre-Flight test is conducted at night and sky conditions are deemed satisfactory for star tracking, the following tests may be used to augment tests described above.

a. Set the clock approximately one minute ahead of the Greenwich Mean Time (GMT).

b. At precisely the Greenwich Mean Time to which the clock has been set turn the SET Switch to GHA. The clock will now indicate Greenwich mean time during the remainder of the pre-flight tests.

c. Set RATE Switch to SID position.

d. Select from the Air Almanac a value of GHA Aries for a time approximately one minute ahead of the GMT, and set this value into the GHA counter.

e. At the precise time for which the GHA of Aries has been chosen, turn the SET Switch to SHA 1.

Note

Do not disturb the GHA or GMT setting by returning the SET Switch to either the GHA or CLOCK position for the remainder of the test.

f. Select three celestial bodies, either stars or planets, of photoelectric magnitude greater than 2.51 (magnitude of polaris) whose altitudes and bearings to the aircraft conform a closely as possible to the table below.

STAR No. 1—Alt, 20-30° -Brg, 0-120°

STAR No. 2—Alt, 30-40° -Brg, 120-240°

STAR No. 3—Alt, 40-50° -Brg, 240-360°

g. Set the SHA of celestial body No. 1 into STAR DATA Panel No. 1.

h. Set the DEC of celestial body No. 1 into STAR DATA Panel No. 1.

i. Set the SHA of celestial body No. 2 into STAR DATA Panel No. 2.

j. Set the DEC of celestial body No. 2 into STAR DATA Panel No. 2.

k. Set the SHA of celestial body No. 3 into STAR DATA Panel No. 3.

l. Set the DEC of celestial body No. 3 into STAR DATA Panel No. 3.

m. Insure that BATH is being fed to the Astro Compass.

n. Place the Power switch in STAR position, the STAR switch in position "1" and allow approximately one minute for the tracker to search for and acquire star No. 1.

o. When TRACK light No. 1 is illuminated indicating that the star is being tracked, note the value of TRUE HEADING and the value of ALTITUDE INTERCEPT.

p. Place the STAR Switch in position "2" and allow approximately one imnute for the tracker to search for and acquire star No. 2.

q. When TRACK light No. 2 is illuminated, note the value of TRUE HEADING and the value of ALTITUDE INTERCEPT.

r. Place STAR Switch in position "3" and allow approximately one minute for the tracker to search for and acquire star No. 3.

s. When TRACK light No. 3 is illuminated note the value of TRUE HEADING and the value of ALTI-

TABLE VII

INPUTS — COMPUTER TESTS

PROBLEM NUMBER	LONGITUDE	GHA	SHA	DEC	LATITUDE	OUTPUTS CALCULATED HO211 AZ
1	W 90° 00′	90° 00′	48° 26′	N 26° 00′	N 19° 09′	288° 00′
2	W180° 00′	180° 00′	17° 00′	N 5° 30′	S 19° 17′	324° 00′
3	W 90° 00′	270° 00′	180° 00′	N 15° 00′	0° 00′	0° 00′
4	E 15° 10′	90° 00′	270° 00′	N 38° 30′	S 40° 17′	348° 00′
5	0° 00′	0° 00′	55° 16′	S 8° 00′	N 40° 06′	240° 00′
6	0° 00′	140° 20′	0° 00′	N 56° 30′	N 59° 17′	336° 00′

TUDE INTERCEPT. Note also the value of HEADING CORRECTION.

t. Place STAR Switch in OFF position.

u. Move HEADING CORRECTION counter 3 degrees from value noted in "s".

v. Place STAR Switch in position "3" and allow approximately one minute for the tracker to search for and acquire star No. 3 to verify ability of tracker to search and acquire a star 3 degrees from the telescope line of sight.

w. The values of TRUE HEADING noted shall not vary more than twenty minutes while tracking each of the three stars while the values of ALTITUDE INTERCEPT shall not vary more than twenty-one minutes.

x. While tracking a star, switch PHOTOTUBE switch on Master Control Panel between positions "1" and "2". TRUE HEADING shall not vary more than two minutes.

y. Place Power Switch in AURORA FILTER position. Tracking shall continue with no change in heading.

3-21. **SUN TRACKING TESTS.** Whenever a Pre-Flight test is conducted during daylight hours and sky conditions are deemed satisfactory for sun tracking, the following tests may be used to augment ground tests.

a. Set clock to GMT.

b. Set Rate Switch to SOL position.

c. Set GHA using GHA sun instead of GHA Aries.

d. Set the SHA counter on each of the Star Data Panels to zero.

e. Set the DEC of the sun as listed for the current hour in the Air Almanac into each of the Star Data panels.

f. See that Power switch is left in SUN position.

g. Note to see that TRUE HEADING and ALTITUDE INTERCEPT shall not vary more than two minutes as each of the STAR DATA packages is selected.

h. Place Power switch in STAR position. The SUN warning light shall light within 5 seconds, indicating that the phototube protect circuit is operating.

3-22. IN FLIGHT CHECKS.

3-23. The following paragraphs will describe procedures the operator will follow periodically during operation. Indications other than those described may imply possible trouble.

a. Altitude Intercept—The operator should monitor the ALTITUDE INTERCEPT counter. When operating in the AUTO mode of operation, ALTITUDE INTERCEPT should read near zero. Large values of this function not consistent with actual conditions indicate either faulty operation or incorrect input information. Check all inputs, internal and external.

b. Heading Correction—The operator should monitor the HEADING CORRECTION counter. When operating in the AUTO mode of operation, and applied BATH is compensated for magnetic variation, heading correction should read near zero. Values in excess of approximately one degree may indicate either faulty operation or improper input information. IF BATH is not compensated for magnetic variation, heading correction should read approximate value of variation for the position of the aircraft.

c. Altitude—The operator should monitor the ALT dial. As the indication approaches the limit of good tracking as indicated by the cross hatched area on the dial, the operator should switch to a new star in a more favorable position.

d. TRACK Lamp—The operator should monitor the TRACK lamps. Illumination of the lamp associated with the numbered position of the STAR switch indicates that the system is tracking. If the appropriate lamp is not illuminated, the system is not tracking. Check visibility of the selected body.

3-24. The following procedures should be noted if the system fails to track the selected body.

a. A frequent cause for failure to track is faulty information. Check all inputs including externally generated latitude, longitude and BATH. Recheck values taken from the Air Almanac. Check counters not only for numerical value but also for correct flag (N, E, S, W). Where heading correction is applied manually, check for correct sign. Where heading correction should be zero, check to see that it is. If sun or planet tracking, check to see that SHA counter reads zero. Check to see that externally generated inputs are actually driving.

b. Switches—Check for proper positioning of switches. Power switch should be in the STAR position for star tracking or the SUN position for sun tracking. RATE switch should be in the SID position for star tracking and SOL position for sun tracking. See Table III for RATE switch positions for planet tracking. Check SET switch for other than GHA position. Check STAR switch for appropriate tracking mode position. Check LAT-LONG switch for AUTO position if accepting externally generated latitude and longitude and MANUAL position for manually set latitude and longitude. Check associated switches on external equipment.

c. Time Drive—Check the GMT clock against a stop watch for one minute. Improper clock rate (about six seconds slow in a minute) reflects improper time drive throughout the system which will cause failure to track. There is no remedial action available to the operator to correct this malfunction.

d. Tracking Conditions—Check the star for visibility. Check sky condition and star altitude. Try an alternate star. If auroral displays are in evidence, turn the Power switch to the AURORA position.

e. Phototube — Check for malfunctioning phototube by switching the PHOTOTUBE selector switch to the number "2" position. Allow the system approximately two minutes in phototube "2' position.

f. Check indicator power fuses on the Power Supply

package. If the fuse indicator is illuminated, the fuse is inoperative. Replace with fuse of appropriate value from spares on bottom of front panel.

3-25. POST MISSION—IN FLIGHT CHECKS.

3-26. The following procedures will determine operability of the system in preparation for the following missions. These checks should be performed on return from a mission as close to the termination of the flight as is practical.

a. Follow preflight check procedure as described in paragraph 3-7 through 3-20.

b. Set up system for tracking. For daylight operation set sun information on STAR DATA 1, 2 and 3 panels. For night operation set up three stars that will be at about forty-five degrees in altitude and separated by about 120 degrees during the period of the check. If possible select stars that will range in magnitude between plus 2 and minus one.

c. Set STAR switch in number "1" position.

d. Note that TRACK lamp number "1" illuminates within one minute.

e. Set STAR switch in number "2" position.

f. Note that TRACK lamp number "2" illuminates within one minute.

g. Set STAR switch in number "3" position.

h. Note that TRACK lamp number "3" illuminates within one minute.

i. With the system tracking attempt to slew HEADING CORRECTION counter. This should not slew.

j. Turn phototube switch to position 2 and note that system continues to track.

k. Set present latitude and longitude on the Manual Present Position display panel.

l. Position LAT-LONG switch to the MANUAL position.

m. Note that the system continues to track and that ALTITUDE INTERCEPT and HEADING CORRECTION does not change.

n. Select to track a body with an azimuth of approximately 90 degrees or 270 degrees, or if no body is available at these azimuths select a body with an azimuth of approximately zero or 180 degrees.

o. If the azimuth of the selected body is nearer east and west slowly slew the LONGITUDE counter. If the azimuth of the body is more nearly north and south slowly slew the LATTITUDE counter.

p. As the counter changes, note an appropriate corresponding change in ALTITUDE INTERCEPT counter.

q. Continue changing the selected function slowly until ALTITUDE INTERCEPT reads approximately 150 nautical miles.

r. Turn the STAR switch to the OFF position and note return of ALTITUDE INTERCEPT counter to zero. Turn LAT-LONG switch to AUTO position.

s. Turn the STAR switch back to the star previously tracked and note that the system begins to track within one minute. Note reading on HEADING CORRECTION counter.

t. Turn the STAR switch to the OFF position. Manually set HEADING CORRECTION counter approximately three degrees from its original value.

u. Turn STAR switch to track star previously being tracked. Note that appropriate TRACK lamp illuminates within one minute and that HEADING CORRECTION returns approximately to original reading when the system is tracking.

SECTION IV.
EMERGENCY OPERATION

4-1. INTRODUCTION.

4-2. This section describes the procedures where externally generated input functions fail (latitude, longitude and best available true heading), and the process by which the system may be used to develop present position information where other methods are not available.

4-3. MANUAL OPERATION.

4-4. In the event that externally generated latitude and longitude inputs fail, the MD-1 may be operated manually by application of internally generated latitude and longitude. The following paragraphs describe the procedure for manual latitude and longitude operation.

a. Place the SET Switch in MANUAL SET position, the MANUAL SET switch in LAT position and the LAT-LONG switch in the MANUAL position. Displace the Set Control to set in the correct latitude on the LATITUDE counter on the Manual Present Position Display Panel.

b. With the SET Switch in MANUAL SET position and the LAT-LONG switch in MANUAL position, place the MANUAL SET switch in LONG position. Displace SET CONTROL to set in the correct Longitude on the LONGITUDE counter on the Manual Present Position Display Panel.

Note

The accuracy of the Latitude and Longitude applied to the system affects the accuracy of

the system outputs. Therefore, for manual operation corrected latitude and longitude information must be applied to the system as often as possible.

c. Proceed as per paragraph 2-13.

4-5. EMERGENCY BATH.

4-6. In the event that externally generated Best Available True Heading inputs fail, the following procedures will aid the operator in acquiring a star and determining an accurate true heading. Once the system is tracking, TRUE HEADING output will be accurate regardless of inoperative BATH input.

a. Set up the system for a celestial body in either the manual or automatic mode of operation.

b. Determine a value for true heading by any available means.

Note

Preliminary true heading need be accurate to within only plus or minus four dgerees. Errors in relative bearing generated on the basis of this information will permit the tracker to search outward to include the stars so long as the error is not greater than four degrees.

c. Place the SET switch in the MANUAL SET position and the MANUAL SET switch in the HDG. CORR. position.

d. With the SET CONTROL drive the HEADING CORRECTION counter. TRUE HEADING counter will change accordingly.

e. Drive HEADING CORRECTION until TRUE HEADING counter reads the value determined in b.

f. Place the STAR switch in the appropriate position for tracking and allow two minutes for the tracker to locate and track the star.

g. If the system does not start tracking within the two minutes, increase TRUE HEADING by driving the HEADING CORRECTION counter approximately four degrees.

h. Allow the system to search for two minutes.

i. If the system does not acquire a star within two minutes, decrease TRUE HEADING by driving the HEADING CORRECTION counter apporximately eight degrees.

j. Allow the system to search for two minutes.

k. Continue to expand the manual search in four degree increments until reasonably sure the star should have been sighted or until star is located.

CAUTION

When the system starts tracking following this procedure, make a careful check to determine that the body sighted is the correct body. Recheck MD-1 true heading against an alternate source. Check ALTITUDE INTERCEPT counter for excessive values.

4-7. LINE OF POSITION IN MANUAL.

4-8. Where present position information generated by external equipment is unavailable, the MD-1 may be used to determine a line of position or a celestial fix operating entirely in the manual mode. The following paragraphs describe development of information for a two star fix.

a. Set GHA of Aries (or sun) on GHA counter and "hack" at moment for which it is set. Check position of RATE switch.

b. Set SHA 1 and DEC 1 for a star, or, if daylight tracking, set SHA to zero and DEC to appropriate value for the sun.

c. Set SHA 2 and DEC 2 for a second star approximately 90° displaced in azimuth from the first.

Note

If a three star fix is desired, choose stars at approximately 120 degree displacement in azimuth. Set the third star on STAR DATA 3 panel.

d. With the SET switch in the MANUAL SET position and the LAT-LONG switch in the MANUAL position, set LATITUDE and LONGITUDE counters for assumed present position. Record this information.

e. Place the Power Switch in the appropriate position and turn the STAR switch to the number "1" position.

f. When the system is tracking, note ALTITUDE INTERCEPT counter, TRUE AZIMUTH counter and time.

Note

Altitude intercept will vary over a period of approximately two minutes as a function of variation in vertical reference due to normal aircraft periodic dynamics. It is suggested the operator determine an average reading over a full period of this major oscillation.

g. Turn STAR switch to the number "2" position (if sun tracking only one LOP will be available).

h. When the system is tracking, note ALTITUDE INTERCEPT counter, TRUE AZIMUTH counter and time.

i. Using information from the Manual Present Position Display panel as assumed present position, plot the LOP's in the usual manner. Do not apply corrections for motion of the observer or motion of the body. However, do advance LOP's for time of fix.

j. If present position is suspected, reset LATITUDE and LONGITUDE counters on the basis of previous fix and repeat. Each succeeding fix should be more accurate.

4-9. LIMIT CONDITIONS.

4-10. HIGH ALTITUDE.

4-11. When the inputs to the Altitude-Azimuth computer are such that the computed altitude is greater than 80°, the computer will be in a high altitude limit condition. The activation of the high altitude limit will be indicated by the following system reactions:

a. The Altitude dial will oscillate around the 80° position.

b. The True Azimuth counter will oscillate.

c. The Altitude limit light will illuminate intermittently.

Note

It may not be possible to observe all three reactions every time this limit condition exists, but some combination of two of the three reactions will occur every time.

4-12. When the computer functions automatically, the limit conditions will be cleared within two minutes, as evidenced by a cessation of oscillations and a decrease in altitude.

4-13. If the oscillations persist for a period longer than two minutes, the limit condition must be cleared manually as follows:

a. Place the "LAT-LONG" switch on the Manual Set Panel in the Manual Position.

b. Slew the longitude counter until the limit is cleared, as evidenced by a cessation of oscillations and a decrease in altitude.

4-14. HEMISPHERE SWITCHING.

4-15. When the Altitude-Azimuth Computer is being driven across the equator so that it is necessary to switch hemispheres, the hemisphere relays in the Junction Box will be activated. The computer may then react in either of two ways.

a. The direction of the inputs will reverse and the azimuth will change by 180°. This reaction may be observed on the True Azimuth counter, which will swing approximately 90° and then return.

b. The computer may start to oscillate as it is driven through the equator. The oscillations can be observed on either the Altitude dial, the True Azimuth counter or both.

4-16. If the computer reacts as described above in "a" the hemisphere will automatically switch and the computer will clear all limits.

4-17. If the computer reacts as described in "b", by oscillating and persists in this mode for more than one minute, reverse the computer by slewing LAT. (manually) and drive it back into the hemisphere from which it came. Then slew latitude fast so that the computer is again driving toward the equator. The computer should now switch hemispheres as described in "a".

4-18. If the Lat. or Long. inputs to the system are cut off, the computer may drift into the hemisphere switching condition. The system will then react as in 4-15, step b and should be brought out of this condition by slewing latitude manually so that the computer moves back into the hemisphere from which it came.

4-19. POLAR LIMIT.

4-20. The Altitude Azimuth computer will be in a polar limit condition when either of the following two conditions exists:

a. When the sum of the Declination and Latitude inputs exceed 170°. This condition will cause the altitude limit light to be steadily illuminated for a short period and then illuminated intermittently.

b. When the inputs to the system are as follows:

LHA between 170° and 190°
LAT greater than 75°
DEC greater than 80°

The sum of LAT and DEC is less than 170°.

Note

This condition will cause the altitude dial and True Azimuth counter to oscillate. (The Alt. light will not be on.)

4-21. The computer may be cleared from both conditions by decreasing the Latitude below 60° 00′.

4-22. When a polar limit condition exists, the declination counter position should not be changed before slewing Latitude according to paragraph 4-21.